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Australian Radiation Protection and Nuclear Safety Agency

SAFETY GUIDE

Predisposal Management of Radioactive Waste (2008)

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Closing date for submissions is **14 March 2008**.

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All submissions will be held in a register of submissions, and unless marked confidential, may be made public.

Radiation Protection Series

The ***Radiation Protection Series*** is published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to promote practices which protect human health and the environment from the possible harmful effects of radiation. ARPANSA is assisted in this task by its Radiation Health and Safety Advisory Council, which reviews the publication program for the ***Series*** and endorses documents for publication, and by its Radiation Health Committee, which oversees the preparation of draft documents and recommends publication.

There are four categories of publication in the ***Series***:

Radiation Protection Standards set fundamental requirements for safety. They are prescriptive in style and may be referenced by regulatory instruments in State, Territory or Commonwealth jurisdictions. They may contain key procedural requirements regarded as essential for best international practice in radiation protection, and fundamental quantitative requirements, such as exposure limits.

Codes of Practice are also prescriptive in style and may be referenced by regulations or conditions of licence. They contain practice-specific requirements that must be satisfied to ensure an acceptable level of safety in dealings involving exposure to radiation. Requirements are expressed in 'must' statements.

Recommendations provide guidance on fundamental principles for radiation protection. They are written in an explanatory and non-regulatory style and describe the basic concepts and objectives of best international practice. Where there are related **Radiation Protection Standards** and **Codes of Practice**, they are based on the fundamental principles in the **Recommendations**.

Safety Guides provide practice-specific guidance on achieving the requirements set out in **Radiation Protection Standards** and **Codes of Practice**. They are non-prescriptive in style, but may recommend good practices. Guidance is expressed in 'should' statements, indicating that the measures recommended, or equivalent alternatives, are normally necessary in order to comply with the requirements of the **Radiation Protection Standards** and **Codes of Practice**.

In many cases, for practical convenience, prescriptive and guidance documents which are related to each other may be published together. A **Code of Practice** and a corresponding **Safety Guide** may be published within a single set of covers.

All publications in the ***Radiation Protection Series*** are informed by public comment during drafting, and Radiation Protection Standards and Codes of Practice, which may serve a regulatory function, are subject to a process of regulatory review. Further information on these consultation processes may be obtained by contacting ARPANSA.

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The mission of ARPANSA is to provide the scientific expertise and infrastructure necessary to support the objective of the ARPANS Act – to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation.

Published by the Chief Executive Officer of ARPANSA in [month 2008]

(Foreword Page)

Foreword

Foreword Text

[signature]

John Loy
CEO of ARPANSA

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1. Introduction

1.1 CITATION

This Safety Guide may be cited as the *Safety Guide for the Predisposal Management of Radioactive Waste (2008)*.

1.2 BACKGROUND

1.2.1 Radioactive waste is generated in Australia through the operation and decommissioning of research reactors, the use of radioactive materials in industry, medicine, education, research and consumer products, the mining and milling of ores and their processing, and in the remediation of contaminated sites. Radioactive waste must be safely managed for the protection of human health and the environment.

1.2.2 The low and intermediate level radioactive waste from research installations, nuclear applications in medicine and industry, and radioisotope production facilities can be diverse and variable in nature, with a wide range of radioactivity levels and containing many different radionuclides.

1.2.3 The radiation protection legislation of the States, Territories and the Commonwealth establish requirements for the safe management of radioactive waste prior to its disposal.

1.2.4 The International Atomic Energy Agency has published Safety Requirements for the *Predisposal Management of Radioactive Waste, including Decommissioning* (IAEA 2000) and the Safety Guides listed in the following table. Recommendations in these IAEA documents were considered in developing the guidance provided in this Safety Guide.

Number	Title	Date
111-G-1.1	Classification of Radioactive Waste	1994
WS-G-2.3	Regulatory Control of Radioactive Discharges to the Environment Supersedes Safety Series No. 77	2000
WS-G-2.5	Predisposal Management of Low and Intermediate Level Radioactive Waste	2003
WS-G-2.6	Predisposal Management of High Level Radioactive Waste	2003
WS-G-2.7	Management of Waste from the Use of Radioactive Materials in Medicine, Industry, Research, Agriculture and Education	2005
WS-G-6.1	Storage of Radioactive Waste	2006

[The following IAEA draft safety guides are at various stages of development and any published before this Australia Safety Guide is issued should be added to the above table]

Number	Title	Date
DS284	Safety Assessment for Nuclear and Radiation Facilities other than Reactors and Waste Repositories <i>Held-up pending development of Safety Requirements on Assessment and Verification.</i>	
DS353	Pre-Disposal Management of Radioactive Waste <i>(A requirements level document to supersede the predisposal part of WS-R-2)</i>	
DS390	Classification of Radioactive Waste <i>(To update SS 111-G-1.1 (1994))</i>	
DS421	Protection of the Public against Exposure to Natural Sources of Radiation including NORM Residues	

31 **1.3 PURPOSE**

32 1.3.1 The purpose of this Safety Guide is to assist regulators, persons
33 responsible for facilities that generate and manage radioactive waste and other
34 specialists in achieving compliance with regulatory requirements.

35 1.3.2 Implementation of the measures recommended in this Safety Guide
36 should ensure that predisposal management of radioactive waste is performed
37 safely with no adverse impact upon public health or the environment and the
38 pretreatment, treatment and conditioning steps described should enable
39 waste to be made suitable for storage and/or disposal.

40 1.3.3 The Safety Guide should also assist in ensuring adequate
41 monitoring, safety assessment and maintenance of radioactive waste in
42 storage, to ensure its ongoing safety and security.

43 1.3.4 The information in this Safety Guide is advisory and does not
44 include regulatory requirements.

45 **1.4 SCOPE**

46 1.4.1 This Safety Guide applies to the predisposal management of the
47 radioactive wastes, including the following:

- 48 • Low and intermediate level radioactive waste from operations such as
49 research reactors, radioisotope production facilities, and from medical,
50 educational, research, industrial and commercial uses of radioactive
51 materials.
- 52 • Low level radioactive wastes that with temporary storage will decay to
53 levels suitable for disposal as very low level radioactive waste.

54 1.4.2 This Safety Guide does not apply to the management of spent
55 reactor fuel, and operational wastes managed at mining and mineral
56 processing sites to which the *Code of Practice and Safety Guide for Radiation
57 Protection and Radioactive Waste Management in Mining and Mineral
58 Processing* (ARPANSA 2005) applies.

59 1.4.3 Predisposal management of waste includes all steps or activities in
60 the management of waste, from its generation up to acceptance for disposal at
61 a repository or other disposal site, disposal as very low level wastes or the
62 removal of regulatory control. Predisposal management may include
63 pretreatment, treatment, conditioning, decommissioning, storage, activities in
64 preparation for transport and any associated activities such as characterising
65 the waste, the waste form or the waste package at appropriate stages.

66 1.4.4 The aim of treatment and conditioning is to prepare waste for
67 disposal by ensuring that the waste will meet the waste acceptance criteria of a
68 disposal facility. Hence this Guide does provide some guidance on mode of
69 disposal for different waste types and generic waste acceptance criteria for
70 disposal. However, the disposal of radioactive waste is not within the scope of
71 this Safety Guide. Requirements for disposal in a near-surface facility can be
72 found in the *Code of Practice for the Near-Surface Disposal of Radioactive*
73 *Waste in Australia* (NHMRC 1992).

74 1.4.5 Some very low level waste or waste streams from the management
75 and processing of radioactive materials may be suitable for discharge to the
76 environment or disposal at a municipal tip. The limits for such waste
77 discharge and tip disposal are proposed to be included in the National
78 Directory for Radiation Protection.

79 1.4.6 Some guidance is given on assessing non-radiological hazards of
80 radioactive waste; however, detailed recommendations on non-radiological
81 hazards are beyond the scope of this Safety Guide.

82 **1.5 STRUCTURE**

83 1.5.1 Specific guidance on managing particular types of waste that occur
84 in Australia is provided in Annexes A to F. Annex G describes generic waste
85 acceptance criteria for disposal.

86 **1.6 INTERPRETATION**

87 1.6.1 This Safety Guide provides guidance on actions, conditions and
88 procedures for managing radioactive waste. Some recommendations in this
89 Safety Guide are expressed as 'should' statements which indicate that the
90 measures recommended be undertaken or equivalent alternative measures be
91 undertaken to comply with regulatory requirements.

92 1.6.2 Other statements indicated by 'may', 'might' or 'could' indicate
93 suggestions for a course of action, but there are likely to be other methods that
94 can achieve the same level of safety.

95 1.6.3 The recommendations and suggestions in this document are
96 guidance and are not to be considered mandatory by a regulator. Alternative
97 measures and methods should be acceptable if they provide a level of safety
98 and effective control equal to or better than the measures and methods
99 described in this Safety Guide.

100

101 **2. Protection of Human Health and the** 102 **Environment**

103 **2.1 GENERAL**

104 2.1.1 The objective of predisposal management of low and intermediate
105 level radioactive waste is to ensure that the waste is managed in a manner that
106 protects human health and the environment, both now and in the future,
107 without imposing undue burdens on future generations. As well as controlling
108 impacts on future human health, the aim should be to limit reliance on actions
109 to be undertaken by future generations. As far as practicable, the predisposal
110 management of waste should not rely on complex long term institutional
111 arrangements or actions as a necessary safety feature.

112 2.1.2 Radioactive waste should be treated and conditioned to enhance its
113 long term safety and security. If there is an established disposal facility, the
114 waste should be treated and conditioned to meet the waste acceptance criteria
115 of the disposal facility. If there is no established disposal facility, undertaking
116 irreversible treatments that might limit future options should be avoided,
117 unless there are clear safety and security benefits. Guidance on this issue is
118 provided in Section 4.4.

119 2.1.3 Where the predisposal management of radioactive waste has the
120 potential for release or migration of radionuclides beyond jurisdictional
121 boundaries, the effects beyond the boundaries should be discussed with the
122 regulator in the neighbouring jurisdiction.

123 2.1.4 A safety culture should be fostered and maintained in organisations
124 involved in the predisposal management of radioactive waste, from its
125 generation to its eventual disposal, so as to encourage an enquiring, learning
126 and self-disciplined attitude to protection and safety and to discourage
127 complacency.

128 **2.2 RADIATION MANAGEMENT PLAN**

129 2.2.1 A Radiation Management Plan which describes the operations and
130 procedures for managing the radiation exposures of staff and the public
131 should be prepared.

132 2.2.2 The radiation exposure of any person as a result of activities in the
133 predisposal management of radioactive waste should be optimised, with due
134 regard to dose constraints and with exposures of individuals kept within
135 specified limits. In designing a facility and planning operations, the
136 responsible person should take into account the possible exposures to both
137 workers and the public. The doses should be kept below established dose
138 limits and as low as is reasonably achievable (ALARA), economic and social
139 factors being taken into account.

140 2.2.3 Optimisation and limits are described in Radiation Protection
141 Series No. 1: Recommendations for Limiting Exposure to Ionizing Radiation

142 (Printed 1995 – Republished 2002) and the National Standard for Limiting
143 Occupational Exposure to Ionizing Radiation (Printed 1995 – Republished
144 2002) (ARPANSA 2002).

145 2.2.4 Operations and procedures should be optimised to ensure that the
146 magnitude of individual doses, the number of people exposed, and the
147 likelihood that potential exposures will occur should all be kept as low as
148 reasonably achievable, economic and social factors being taken into account
149 (ALARA). Optimisation takes into account good practice at the facility and
150 other similar, well managed facilities. Strategies are ranked in order of
151 reduction in detriment and an optimum is reached when any further step to
152 reduce the detriment would involve resources out of proportion to the
153 consequent reduction (ARPANSA 2002).

154 2.2.5 The Radiation Management Plan should include processes and
155 procedures for dealing with incidents and accidents and define responsibilities
156 for emergency response.

157 **2.3 RADIOACTIVE WASTE MANAGEMENT PLAN**

158 2.3.1 For radioactive waste management facilities that treat or condition
159 radioactive waste, a Radioactive Waste Management Plan should be prepared
160 that describes the process to be undertaken and demonstrates operations can
161 be undertaken safely and securely with minimal impact on the environment.
162 A Radioactive Waste Management Plan should also be prepared if significant
163 changes are made to an existing licensed facility or for facilities that store
164 liquid wastes for short term decay, such as iodine-131 holding tanks.

165 2.3.2 Most facilities that only store solid radioactive waste do not require
166 a Radioactive Waste Management Plan. However, preparation of a
167 Radioactive Waste Management Plan may be appropriate for a facility storing
168 a substantial amount of radioactive waste.

169 2.3.3 Examples of sound operational and engineering practices and
170 administrative controls that could be included in a Radioactive Waste
171 Management Plan include:

- 172 (a) Thorough planning for and careful execution of activities for the
173 management of waste, including the eventual decommissioning
174 of the facilities;
- 175 (b) Pre-work assessments and use of training mock-ups to
176 minimise exposures during operational and maintenance
177 activities, if warranted by the hazards;
- 178 (c) The use of remote handling technologies for operational and
179 maintenance activities, if warranted by the hazards;
- 180 (d) Establishing controls, such as activity limits and checking by
181 trained personnel, if items are transferred or removed from
182 areas of higher contamination to areas of lower contamination;
183 and

184 (e) Verifying the adequacy of controls to limit the exposure of
185 workers and the public by means of personal, area and
186 discharge monitoring.

187 2.3.4 The Radiation Management Plan should include a safety
188 assessment. Guidance on undertaking such safety assessments is provided in
189 Section 2.5.

190 2.3.5 The Radioactive Waste Management Plan does not need to repeat
191 information available elsewhere in the facility management system, but it
192 should provide references to relevant procedures, responsibilities and
193 schedules. The facility should have clear assignment of responsibilities,
194 procedures, processes and schedules for managing radioactive waste.
195 Guidance on management systems and quality assurance is provided in
196 Section 2.6.

197 2.3.6 A facility for the predisposal management of waste should be
198 designed so that as far as possible incidents will be avoided and accidents
199 prevented, and if they do occur the consequences will be mitigated. All stages
200 in treatment and conditioning should be assessed systematically using a
201 HAZOPs (Hazard and Operability) analysis to identify hazards. The HAZOP
202 method is a structured multidisciplinary team approach to hazard analysis.
203 Hazards should be eliminated if practicable; if not, they should be minimised
204 by means of changes to the design or to operational procedures. Results of
205 any HAZOPs analyses should be included in the Radioactive Waste
206 Management Plan.

207 2.3.7 The design and operation of facilities for the predisposal
208 management of radioactive waste should take into account any potential
209 hazards due to other non-radioactive physical or chemical characteristics of
210 the waste. Protection from non-radiological hazards should be provided in
211 accordance with the relevant standards on health and safety and
212 environmental protection.

213 2.3.8 Decommissioning should be considered in the design of larger
214 facilities to be used for the predisposal management of radioactive waste.
215 Design options and operating practices that will facilitate the
216 decommissioning of the facility should be chosen, and a decommissioning
217 plan that can be updated during the life of the facility should be prepared.

218 **2.4 APPROVALS AND AUTHORISATIONS**

219 2.4.1 Radioactive waste management facilities can be diverse and each
220 facility may need to be assessed and approved differently. Discussions with
221 the regulator should be initiated early in project development so that the
222 approval requirements are understood and incorporated into the project
223 timeline.

224 **2.5 SAFETY ASSESSMENT**

225 2.5.1 A Safety Assessment should be prepared as part of the Radioactive
226 Waste Management Plan. A Safety Assessment provides the basis for the
227 safety case that demonstrates the facility can operate safely and the proposed
228 pretreatment, treatment, conditioning and storage operations can be
229 undertaken safely. The detail, scope and rigour of such an assessment will
230 depend on the nature of the waste management operations and on the
231 radiological hazard.

232 2.5.2 If waste management is one activity of a larger facility, the Safety
233 Assessment Report of the overall facility could include assessment of the
234 waste management activities. There may be no need to produce a separate
235 Safety Assessment Report for operations involving management of waste.

236 2.5.3 The Safety Assessment Report should address the impacts of
237 routine waste operations and any credible abnormal occurrences. The
238 assessment should demonstrate that the appropriate measures required for
239 normal operation and minimise the likelihood of incidents or accidents are in
240 place and that the consequences of such an event would be mitigated. The
241 Safety Assessment Report should include a safety case demonstrating that the
242 facility can operate safely.

243 2.5.4 The Safety Assessment Report should describe the structure,
244 systems and components of the facility, the waste to be processed and all the
245 associated operations for both normal operations and in the event of an
246 incident or accident. The safety assessment should identify possible incident
247 and accident scenarios which might occur. The aim of the safety assessment is
248 to demonstrate that the performance objectives are satisfied for the possible
249 incidents and accidents and that the overall process is acceptable for licensing
250 or authorisation. The results should include predicted impacts on the
251 workers, the public and the environment.

252 2.5.5 Depending on the nature of the waste management operations and
253 the radiological hazard, the Safety Assessment Report for a waste
254 management facility could include:

- 255 (a) A description of the components of the facility, the site and
256 surrounds that are relevant to the management of the waste to
257 be processed or stored in the facility;
- 258 (b) A list of relevant regulations and safety guidelines pertinent to
259 each stage of the waste management operation;
- 260 (c) The identification of relevant safety criteria required by the
261 regulatory body; including design and performance
262 expectations relevant to the waste processes, operations and
263 activities and the criteria for an acceptable radiological impact.
264 The consequences included in the safety criteria would
265 normally include impact on workers, the public and the
266 environment;

- 267 (d) The identification of normal and abnormal operating scenarios
268 that encompass the range of what could credibly go wrong.
269 Conditions, processes and events that potentially influence the
270 integrity and safety of waste operations and that might
271 originate outside or inside the facility should be considered;
- 272 (e) The data and information used to assess the scenarios, the
273 source of the data and its accuracy;
- 274 (f) A description of the conceptual and/or mathematical modelling
275 used to assess the scenarios and quantify the potential
276 consequences. Abnormal operational conditions should be
277 assessed based on their consequences and likelihood;
- 278 (g) Input data used in conceptual and/or mathematical modelling,
279 which should be clearly referenced, including the source and
280 accuracy of data used;
- 281 (h) A comparison of the results of the safety assessment with the
282 safety criteria;
- 283 (i) If the safety assessment does not meet the safety criteria, then
284 the results of the assessment should be used to determine
285 whether more accurate modelling, changes to facility design,
286 changes to operating procedures or whether the proposal
287 should be abandoned. Sensitivity and uncertainty analyses may
288 identify the parameters that most affect the results of the safety
289 analysis. Preparation of a safety assessment may be an iterative
290 process, performed until a facility design and operational
291 system can be demonstrated to meet all safety requirements;
292 and
- 293 (j) Documentation of the results of the safety assessment.

294 2.5.6 Assumptions made in conducting the safety assessment should
295 encompass the range of operations that will occur in practice and a realistic
296 range of abnormal incidents and accidents in relation to waste management.
297 The safety assessment should be repeated if proposed processes or operating
298 procedures are outside the envelope of processes or procedures assumed in
299 the original safety assessment or if a new incident or accident scenario is
300 identified.

301 2.5.7 Conditions, processes and events that originate outside the facility
302 should be identified on a site specific basis. Challenges to safety that originate
303 within the facility should be based on the nature of the facility and on the
304 processes and activities that take place in it. Annexes to the IAEA Safety
305 Guide on Predisposal of Radioactive Waste (IAEA 2003) provide lists of
306 possible conditions, processes and events for consideration in the safety
307 assessment of a major facility for the management of radioactive waste.

308 2.5.8 The Safety Assessment Report should include an assessment of the
309 radiological impact of liquid and gaseous releases that may be routinely or
310 abnormally discharged to the environment from the facility. The adequacy of
311 equipment used to monitor and control the levels of such discharges should

312 also be assessed. There is no need to assess the radiological impact of releases
313 of very low levels of radioactivity that satisfy the requirements and limits for
314 the disposal of radioactive waste by the user proposed to be included in
315 Schedule 8 of the National Directory for Radiation Protection. The regulator
316 could have more specific requirements and guidance on acceptable levels for
317 any liquid and gaseous releases.

318 2.5.9 The Safety Assessment Report should be reviewed periodically and
319 updated as necessary on the basis of the information gathered by monitoring
320 the workplace and the environment. The facility should have a modifications
321 policy which includes an assessment of whether a proposed modification
322 potentially changes the safety case. If changes are to be made to the
323 operational procedures or facility design, the assessment should demonstrate
324 the potential risks have not increased as a result of these changes. Significant
325 modifications to procedures or design may require regulatory approval.

326 2.5.10 Records all incidents and accidents (and also of incidents and
327 accidents that were averted) should be periodically reviewed to determine if
328 the safety assessment needs to be updated.

329 2.5.11 The safety assessment may identify features important to the safe
330 operation of the facility or activity. These features should receive special
331 consideration in the Radiation Management Plan and the Radioactive Waste
332 Management Plan.

333 **2.6 MANAGEMENT SYSTEM (QUALITY ASSURANCE)**

334 2.6.1 The term 'management system' describes the integrated system
335 that brings together requirements for safety management, quality
336 management, environmental management, security and business
337 management.

338 2.6.2 The management system should focus on important safety, security
339 environmental and business issues. The level of detail and control in the
340 management system should be commensurate with risk of adverse outcomes.

341 2.6.3 A larger organisation might already have a management system
342 applying to all operations of the organisation operating the facility. If there is
343 no overall organisational management system, then a management system
344 should be implemented for the predisposal management of the radioactive
345 waste.

346 2.6.4 The management system should meet the international quality
347 management system standard ISO 9001 (2000) and the IAEA safety
348 requirements for management systems for nuclear facilities and activities
349 (IAEA 2006a). The IAEA Safety Guide (IAEA 2006b) provides guidance on
350 implementing management systems for nuclear facilities and activities
351 including facilities radioactive waste management facilities.

352 2.6.5 The management system should address the managerial tasks,
353 including planning and scheduling activities, responsibilities and the use of
354 resources. These tasks and the results of the activities should be documented.

355 The responsibilities and authorities of the personnel and organisations
356 involved should be clearly specified. Procedures for business critical processes
357 should be part of the management system. The management system should
358 be identified in proposal submitted for approval by the regulatory body.

359 2.6.6 Quality control should be applied to all stages and elements of the
360 predisposal management of radioactive waste. Quality control in the
361 management system should be at a level to demonstrate effective control of
362 the radioactive waste and demonstrate that the waste meets physical, chemical
363 and containment requirements at each stage of the predisposal management
364 activity and for acceptance of the waste for disposal.

365 2.6.7 The management system should include procedures and processes
366 for:

- 367 (a) Characterisation of the waste;
- 368 (b) Development of the specifications for packages for radioactive
369 waste;
- 370 (c) Approval of the conditioning process for the waste;
- 371 (d) Confirmation of the characteristics for waste packages; and
- 372 (e) Review of quality control records.

373 2.6.8 Records generated at all stages of the predisposal management of
374 waste are important for demonstrating the compliance of the waste package
375 with the specifications. Such records should ensure the traceability of the
376 characteristics of the waste from its generation through to its processing and
377 storage. A system for managing and archiving documentation should be
378 established. Examples of the contents of such records for waste packages
379 include:

- 380 (a) Characterisation data for the waste as generated;
- 381 (b) Values of the key process parameters for the waste during its
382 pretreatment, treatment and conditioning;
- 383 (c) Calibration records for equipment and systems used for process
384 control;
- 385 (d) Characterisation of the waste form and the associated container
386 (e.g. material certificates for the container and its lid and welds
387 or seals, including quality control tests and their records);
- 388 (e) Values of significant monitoring parameters; and
- 389 (f) Identification of waste packages and storage locations.

390 2.6.9 If no treatment or conditioning facility is available, it may be
391 necessary to store the waste for long periods before disposal. In such cases the
392 record keeping system should be designed to ensure that the quality and
393 integrity of the records, as well as the marking and labelling of waste
394 packages, are of sufficient quality to identify, maintain and preserve such
395 information for sufficient time. An appropriate backup system to protect this
396 information should also be established.

397 2.6.10 An audit programme should be established to verify that the
398 requirements of the management system are being met, procedures are being
399 followed and the correct records are being kept.

400 2.6.11 Audits should be used to verify that waste management processes
401 are being conducted within specified parameters, in compliance with the
402 procedures for safe operation and with the requirements established by the
403 regulatory body in a licence or an authorisation of another type.
404

405 **3. Responsibilities Associated with**
406 **Predisposal Management of Radioactive**
407 **Waste**

408 **3.1 GENERAL**

409 3.1.1 The overall objective of predisposal management of radioactive
410 waste is to produce waste packages that can be handled, transported, stored
411 and disposed of securely and safely. Waste should be conditioned to meet
412 acceptance requirements for its disposal. There should be a clear and
413 documented allocation of responsibility for safety during the entire
414 predisposal management process.

415 3.1.2 The regulator might require pre-operational and commissioning
416 tests prior to granting authorisation to commence operations using
417 radioactive materials to demonstrate compliance with the requirements for
418 design and other safety and security requirements.

419 3.1.3 Owing to the potentially long time periods between the
420 conditioning of radioactive waste and its disposal, the regulator could require
421 assurance that there would be the necessary human, technical and financial
422 resources available when required and that data and records will be
423 maintained for an appropriate period of time.

424 **3.2 RESPONSIBLE PERSON**

425 3.2.1 The Responsible Person is defined as having overall management
426 responsibility for the facility. Prior to commencing the construction or
427 significant modification of any facility for the predisposal management of
428 radioactive waste, the Responsible Person should submit to the regulatory
429 body an application including a Radiation Management Plan and, if required,
430 a Radioactive Waste Management Plan that details the proposed design and
431 operational practices. The application should demonstrate that the proposed
432 operational procedures will provide effective control of the radioactive waste
433 at all times. The application should justify the proposed practices, show that
434 there is a net benefit and demonstrate that the activities can be performed
435 safely and securely.

436 3.2.2 The scope and detail of the application to the regulator should be
437 commensurate with the level of hazard. Waste processing that involves higher
438 risk and larger amounts of waste will require more detailed analysis to
439 demonstrate adequate levels of safety and environmental impact.

440 3.2.3 Any transfer of radioactive waste should be made only to
441 authorised organisations. Prior to any transfer of radioactive waste to another
442 organisation, the responsible person should ensure that:

- 443 (a) The regulator in the jurisdiction to which the waste is destined
444 has been notified and consent for the transfer obtained;

- 445 (b) The accepting organisation possesses sufficient technical and
446 administrative means to manage the waste;
- 447 (c) Continuity of effective control during the transport of
448 radioactive waste is maintained;
- 449 (d) Transport complies with the *Code of Practice for the Safe*
450 *Transport of Radioactive Material (RPS2)* (ARPANSA 2008)
451 and the relevant legislation of all jurisdictions involved; and
- 452 (e) Information is supplied to the intended recipient of the waste
453 and confirmation of intended acceptance of the waste is
454 received.

455 3.2.4 The Responsible Person should accept responsibility for the safety
456 of all activities in the predisposal management of waste, even if the work is
457 contracted to a third party.

458 3.2.5 If the waste is destined for an established disposal facility, the
459 Responsible Person should ensure that the waste package meets the
460 acceptance requirements for that facility. If no disposal facility is available,
461 the Responsible Person should consider the compatibility of the waste
462 package with the anticipated acceptance requirements for disposal, so as to be
463 able to provide reasonable assurance that the conditioned radioactive waste
464 will be accepted for disposal.
465

466 **4. Elements of Predisposal Management of**
467 **Radioactive Waste**

468 **4.1 INTERDEPENDENCIES**

469 4.1.1 Interdependencies exist between the steps in the management of
470 radioactive waste. At the planning phase, various alternatives are usually
471 possible for each step in the management of radioactive waste. All the
472 different steps should be evaluated, as part of an integrated system in which
473 the steps are complementary and mutually dependent. The most appropriate
474 treatment and conditioning options are those that lead to a waste form and
475 package that meets the acceptance requirements of the disposal facility.

476 4.1.2 Personnel and/or organisations responsible for subsequent steps
477 should be fully consulted and informed of proposed processing of the waste.
478 For example, the responsible person of the storage facility should be involved
479 in planning for treatment and conditioning needed to ensure that the
480 packaged waste is suitable for the conditions of the store.

481 **4.2 WASTE MINIMISATION**

482 4.2.1 Low and intermediate level waste is generated by a wide range of
483 activities that use radioactive materials or radioactivity, including the
484 operation and decommissioning of nuclear facilities and the cleanup of sites.
485 The generation of waste should be kept to the minimum practicable. Waste
486 minimisation relates to minimising the total volume of waste and the total
487 amount of radioactivity. All processes that generate waste should be assessed
488 before commencement and regular reviews undertaken to determine if the
489 amount of radioactive waste can be reduced by changes in process design or
490 operational procedures. The chemical characteristics of the waste being
491 generated should also be assessed to optimise subsequent processing of the
492 waste.

493 4.2.2 Waste minimisation aims to reduce the amount of radioactive
494 waste generated at source. Waste minimisation aspects to be considered in
495 facility design include:

- 496 (a) Selection of materials, processes and structures, systems and
497 components for the facility;
- 498 (b) Selection of design options that favour waste minimisation
499 during operations and when the facility is eventually
500 decommissioned;
- 501 (c) Use of effective and reliable techniques and equipment; and
- 502 (d) Clear demarcation of zones and equipment potentially
503 containing radioactivity to prevent spread of contamination.

504 4.2.3 Waste minimisation aspects to consider during operations include:

- 505 (a) Segregating the different types of radioactive waste (e.g. long-
506 lived alpha emitting waste, short-lived beta/gamma waste,

- 507 waste with very low concentrations of radioactivity,
508 concentrated liquids, low concentration liquids) if this
509 segregation optimises subsequent treatment and conditioning
510 steps;
- 511 (b) Minimising the amount of non-radioactive material used in
512 controlled areas to prevent contamination and generation of
513 additional waste;
- 514 (c) Keeping non-radioactive wastes well separated from radioactive
515 waste in a controlled area. Non-radioactive waste should be
516 checked before being removed from a controlled area to
517 confirm it is non-radioactive;
- 518 (d) Planning activities and the use of equipment for handling waste
519 to limit generation of secondary radioactive waste;
- 520 (e) Decontaminating equipment and materials to minimise the
521 volume of waste that is radioactive, together with control of
522 secondary waste arising from decontamination; and
- 523 (f) Recycling and reusing materials and structures, systems and
524 components that are potentially contaminated.

525 4.2.4 Waste contaminated with radionuclides of very short half-life (less
526 than about 60 days) could be collected and stored until the radioactivity
527 decays enough to meet exemption levels in the National Directory for
528 Radiation Protection (ARPANSA 2004).

529 **4.3 WASTE CHARACTERISATION**

530 4.3.1 The effective management of low and intermediate level waste
531 depends on knowledge of the waste characteristics and the contained
532 radioactivity. Until the waste has been characterised, management should be
533 based on conservative assumptions of its physical and chemical properties and
534 the contained radioactivity. Knowledge of the generation process and
535 experience of waste generated earlier from the same process or from similar
536 processes can be used to estimate the characteristics of the waste, but this
537 estimate should be sufficiently conservative to cover the possible range of
538 activities and hazardous properties.

539 4.3.2 Characterisation of radioactive waste may occur in several stages.
540 Knowledge of the generation process provides the first estimate of the
541 characteristics of waste; then direct measurements improve the information
542 on the properties of the waste. The initial measurement could be determining
543 the dose rate emitted from the waste. Later measurements could be by
544 gamma spectroscopy, and waste could be sampled for further analysis, e.g.
545 alpha, beta spectroscopy and/or chemical analysis. The aim of waste
546 characterisation is to define waste properties sufficiently to demonstrate
547 acceptance for successive waste management steps, and ultimately to meet
548 waste acceptance criteria for the disposal facility.

549 4.3.3 Consideration should be given to segregating different types of
550 radioactive waste to facilitate waste management and optimise subsequent

551 treatment and conditioning steps. A decision to segregate different types of
552 waste should be based on a risk based analysis that demonstrates safety,
553 security or management benefits. Segregation can be justified if it allows a
554 significant amount of waste to be classified at a lower level of hazard and/or
555 reduce the amount or volume of waste that is classified at a higher level of
556 hazard.

557 4.3.4 It may be advantageous to segregate waste on the basis of half-life
558 to facilitate appropriate management, and meet the categories in waste
559 acceptance criteria for disposal. It is suggested that radioactive waste be
560 categorised into three half-life categories:

- 561 (a) short-lived sources with half-life less than 6 years (i.e. includes
562 cobalt-60 with half-life 5.3 years);
- 563 (b) medium-lived sources with half-life more than 6 years but less
564 than 40 years (i.e includes caesium-137 with half-life 30.1 years
565 and strontium-90 with half-life 28.8 years); and
- 566 (c) long-lived sources with half-life more than 40 years.

567 4.3.5 The above categories of 6 years and 40 years half-life are consistent
568 with the Near-Surface Disposal Code (NHMRC 1992). The Near-Surface Code
569 uses ≤ 5 years and ≤ 30 years but as rounded numbers and this means that
570 Co-60 with a half-life of 5.3 years is considered to be short-lived waste and
571 Cs-137 with a half-life of 30.1 years is included in ≤ 30 years. Using 6 years
572 and 40 years makes clear that Co-60 is included in the short-lived category
573 and Cs-137 is included in the medium life category.

574 4.3.6 Radioactive waste could also be segregated on the basis of the level
575 of radioactivity and the radiotoxicity of the contained radionuclides. An
576 indication of the radiotoxicity of the radionuclide(s) is the exemption level
577 given in the National Directory for Radiation Protection (ARPANSA 2004). It
578 may be worthwhile to segregate waste containing mainly alpha emitting
579 radionuclides from waste with no or very low levels of alpha emitting
580 radionuclides because alpha emitters usually have higher radiotoxicity than
581 non-alpha emitters, and require better containment and may need to be
582 treated differently for disposal.

583 4.3.7 Some waste generated in a controlled facility may be able to be
584 treated as non-radioactive waste if it can be demonstrated by measurement
585 that the radioactivity of all radionuclides is below the exemption limit listed in
586 the National Directory for Radiation Protection (ARPANSA 2004). The
587 responsible person should check to ensure that the process proposed to
588 exempt waste meets the requirements of the regulator. Where the operator is
589 unsure, or does not have appropriate measurement facilities, they may choose
590 to consult with the regulator on the whether the waste meets exemption limits.

591 **4.4 WASTE PROCESSING**

592 4.4.1 Radioactive waste processing can be divided into three steps (IAEA
593 Glossary 2003):
594

595 **Pretreatment** includes any or all of the operations prior to waste
596 treatment, such as collection, segregation, chemical adjustment and
597 decontamination.

598
599 **Treatment** includes operations intended to benefit safety and/or
600 economy by changing the characteristics of the waste. Three objectives
601 of treatment are: volume reduction, removal of radionuclides and
602 change of composition. Treatment may result in an appropriate waste
603 form.

604
605 **Conditioning** includes those operations that produce a waste package
606 suitable for handling, transport, storage and/or disposal. Conditioning
607 may also include the conversion of the waste to a solid waste form,
608 enclosure of the waste in containers, and, if necessary, provision of an
609 overpack.

610 4.4.2 In the deciding on treatment and conditioning processes,
611 consideration should be given to the suitability of the resultant waste packages
612 for transport and storage, including retrieval, and to their suitability for
613 emplacement in a disposal facility on the basis of the anticipated disposal
614 waste acceptance requirements.

615 4.4.3 In many cases, decisions about predisposal management of
616 radioactive waste have to be made before waste acceptance requirements for
617 disposal are known. If the final disposal route is not known or has not been
618 chosen, planning for earlier steps should consider a realistic range of options.
619 Processing or conditioning steps selected for particular waste types should not
620 impose significant constraints on following steps in managing the waste or
621 foreclose viable options. Irreversible conditioning processes should be
622 avoided until all steps are fully defined.

623 4.4.4 In some cases however, safety and/or security benefits can be
624 sufficiently persuasive to justify undertaking irreversible treatment or
625 conditioning processes. For example, solidification of liquid waste is nearly
626 always justified by the increased safety associated with storing solids rather
627 than liquids. If there is sufficient safety or security justification for
628 undertaking irreversible conditioning, the responsible person should prepare
629 an assessment to demonstrate the benefits of the proposed action. The
630 generic waste acceptance criteria in Annex G and waste acceptance criteria of
631 similar overseas disposal facilities may provide sufficient information to allow
632 a case to be made for treating and conditioning.

633 4.4.5 The assessment of the benefits of undertaking irreversible
634 processing should be included in the application to the regulator seeking
635 approval for undertaking the proposed waste treatment. However, even if the
636 regulator approves the application to undertake the proposed waste
637 processing, it is the Responsible Person who takes responsibility that the
638 processed waste will be acceptable for a waste disposal when the waste
639 disposal facility comes into operation.

640 4.4.6 A waste package should have a durable label bearing an
641 identification number, weight, and contact dose rate. Other properties of the
642 waste package should be easily retrievable from records. A proper record of
643 each waste package should be kept in a records management system. Records
644 should be securely stored, easily accessible and retrievable over an extended
645 period.

646 4.4.7 Information recorded for each waste package should include:

- 647 (a) the identification number of the package;
- 648 (b) radionuclide and activity content;
- 649 (c) a description of the area in which the source was utilised;
- 650 (d) details of the package contents – type of source containment,
651 conditioning matrix and matrix containment;
- 652 (e) mass;
- 653 (f) the external size and/or volume of the package;
- 654 (g) the maximum dose rate at contact and at 1m, and the date of
655 measurements; and
- 656 (h) the presence and activity of fissile materials, if any.

657 4.4.8 Annexes to this Safety Guide provide specific guidance on
658 pretreatment, treatment and conditioning for the following six types of waste:

- 659 (a) Devices containing low levels of long-lived alpha emitters (dials
660 and luminous devices containing radium and smoke alarms)
661 (Annex A);
- 662 (b) Devices containing higher levels of long-lived alpha emitters
663 (radium needles and tubes, neutron detectors) (Annex B);
- 664 (c) Disused sealed sources of low radioactivity (<100 MBq) and
665 gaseous tritium light sources) (Annex C);
- 666 (d) Disused sealed sources of higher radioactivity (>100 MBq)
667 (Annex D);
- 668 (e) Laboratory and medical waste (Annex E); and
- 669 (f) Residues from industrial processing and waste from
670 remediation of contaminated sites (Annex F).

671 **4.5 WASTE STORAGE**

672 4.5.1 Radioactive waste storage is required at all stages of waste
673 management to provide isolation from humans, safety, security and
674 environmental protection. The IAEA has developed recommendations on the
675 planning, siting, design and operation of radioactive waste storage facilities
676 [Storage of Radioactive Waste, IAEA Safety Guide WS-G-6.1, 2006].

677 4.5.2 The siting of a radioactive waste storage facility depends on the
678 radiological hazards associated with the stored waste. The level of siting
679 requirements and the rigour and scope of the safety assessment for waste

680 storage facilities depend on the potential radiological hazard of the waste
681 stored and the activities to be undertaken in the store.

682 4.5.3 Waste storage facilities can be:

683 (a) part of a hospital, university, industrial site or small research
684 institute where the use of radioactive materials is incidental to
685 the main objective of the facility and the amount of radioactivity
686 in storage is relatively small;

687 (b) associated with nuclear installations such as research reactors
688 or radiopharmaceutical production facilities where the site
689 selection may be based on the factors important for the main
690 facility and approval for the main facility will include the
691 storage facility; and

692 (c) isolated facilities receiving a wide variety of waste from a
693 number of different sources but built separately from other
694 licensed facilities.

695 4.5.4 The level of the siting requirements for all waste storage facilities
696 depend on the potential radiological hazard of the stored waste.

697 4.5.5 The storage of waste in centralised facilities rather than a multitude
698 of small on-site facilities should be considered, since there are opportunities
699 to realise economies of scale and provide better long-term security and safety
700 of the stored waste.

701 4.5.6 Waste in storage may be in solid, liquid or gaseous form; it might
702 be raw waste, treated waste or conditioned waste ready for transport and
703 disposal. The facilities and procedures should be appropriate for the level of
704 risk and hazard of the stored waste.

705 4.5.7 Inspection procedures should be implemented to detect
706 degradation of waste packages before there is any release of radioactivity from
707 a package, and the facility should be designed with passive features to ensure
708 containment of radioactivity even if such degradation occurs. This might
709 mean, for example, appropriate bunds, floor drains to a holding tank, and/or
710 sealed floors that can be readily decontaminated.

711 4.5.8 Sufficient storage capacity should be provided for waste generated
712 in normal operations, with a reserve capacity for waste generated in any
713 incidents or abnormal events.

714 4.5.9 Storage conditions should ensure waste can be readily retrieved for
715 subsequent steps, e.g. further processing or disposal. Adequate space should
716 be available for inspection of items and checking for contamination before
717 dispatch.

718 4.5.10 Radioactive waste should be stored in packages or containers
719 suitable for the type of storage and foreseeable timeframe of storage. Storage
720 conditions should ensure the integrity of waste in storage is maintained and
721 any degradation minimised. Air conditioning, heating and/or humidity

722 control may need to be provided. The need for active systems to maintain
723 safety should be minimised.

724 4.5.11 Each stored item, storage container or tank containing radioactive
725 liquid should be clearly and uniquely labelled. A description of the radioactive
726 contents, the activity either when stored or most recently determined should
727 also be available.

728 4.5.12 Tanks for the storage of liquids should be constructed of chemically
729 resistant material such as stainless steel, plastic, rubber-lined carbon steel or
730 fibreglass. Secondary containment should be provided around the tank to
731 prevent the spread of contamination in the event of leakage. The provision of
732 adequate shielding should also be considered.

733 4.5.13 Collection and storage tanks should have appropriate equipment
734 for stirring, venting and transferring waste to prevent the build-up of
735 sediment or the accumulation of hazardous gases. Provision should be made
736 for sampling and for reserve capacity if necessary for unplanned events. The
737 floor of the room or area where liquid waste is stored or processed should be
738 sealed against the penetration of liquids for ease of decontamination.

739 4.5.14 Design of the storage facility should permit regular radiation
740 monitoring and inspection of the waste packages to obtain an early indication
741 of any physical deterioration, signs of leakage or build-up of gases in the
742 containers. Radiation monitoring and visual inspection should also be
743 performed whenever the waste is handled or moved (placed into storage,
744 retrieved or transported off the site). There should be enough space in the
745 store for stacking, sorting and visual inspection of packages.

746 4.5.15 Storage facilities with potentially physically mobile forms of waste,
747 i.e., putrescibles, liquids and gases, should have spare redundant containment
748 available should any problems with the integrity of containment arise.

749 4.5.16 The storage facility should be adequately ventilated to exhaust any
750 gas generated in normal operation or under anticipated accident conditions.
751 The potential for gas generation by radiolysis or chemical reaction should be
752 assessed, and if necessary appropriate monitoring undertaken. Stores with
753 waste containing uranium or radium should be monitored for radon levels and
754 radon concentrations should be acceptable before entry of staff. The
755 extraction system should be filtered if there is possibility for emissions of
756 particulate materials. Where appropriate, the removal of radon from
757 extracted air should be addressed in the Radioactive Waste Management Plan.

758 4.5.17 Measures to prevent, detect and control fires should be
759 incorporated into the design of facilities for the storage of combustible waste.
760 The store should be constructed of durable, fire resistant material.

761 4.5.18 The store should be designed to ensure that the dose received by a
762 member of the public located in an accessible area of the store is less than the
763 dose limit of the general public, i.e. less than 1 mSv in a year (ARPANSA
764 2002). The estimate of the dose to a member of the public should be based on

765 conservative assumptions about the possible period that the member of the
766 public could occupy that location.

767 4.5.19 Provision should be made for cooling if there is a potential for
768 heat-generating waste to be present.

769 4.5.20 A document control system should be established to maintain an
770 inventory of all waste in storage, to track the movements of all waste items
771 and to record all inspections and maintenance activities. The management
772 system and quality assurance are further discussed in section 2.6.

773 4.5.21 Appropriate radiation warning signs should be displayed at each
774 entrance to the store and where appropriate on the walls and surrounds of the
775 facility.

776 4.5.22 Potential pathways for environmental emissions from a storage
777 facility should be assessed and those determined to be significant should be
778 monitored to verify that any release of radioactivity is within limits. The level
779 of environmental monitoring should relate to the risk of significant
780 environmental impact. Environmental monitoring should be more
781 comprehensive for a large store than for a small store in a hospital or
782 university. Possible environmental releases to be considered in designing the
783 environmental monitoring program include: airborne emissions, sewer,
784 surface water and ground water.

785 **4.6 ACCEPTANCE CRITERIA FOR RADIOACTIVE WASTE** 786 **DISPOSAL**

787 4.6.1 The objective of treating and conditioning radioactive waste is to
788 produce waste packages that can be handled, transported, stored and disposed
789 of securely and safely. In particular, the final packaging should meet the
790 waste acceptance criteria of the disposal facility.

791 4.6.2 If a disposal facility is not established and the waste acceptance
792 criteria are not known, an assessment should be undertaken to determine the
793 type of disposal appropriate to the particular waste stream and an estimate
794 made of the range of likely waste acceptance criteria for that type of disposal.
795 Generic waste acceptance criteria are discussed in Annex G. In some cases, it
796 may be appropriate for to place packaged waste in an overpack tailored to the
797 specific waste acceptance criteria for the particular disposal facility.

798 4.6.3 Waste acceptance criteria for disposal in a range of facilities are
799 likely to require minimal voids in the waste package, minimal free liquids and
800 that toxic materials are below specified limits.

801

802 **Annex A**

803

804 **Management of Devices Containing Low Levels of Long-**
805 **Lived Alpha Emitters (Dials and Luminous Devices and**
806 **Smoke Alarms)**

807 This Annex covers the management of luminous watches containing radium, smoke
808 alarms containing americium and similar items uses where the amount of
809 radioactivity per item is less than about 100 kBq.

810 **Issues Relating to Dials and Luminous Devices containing Radium**

811 Luminous paint containing radium-226 was used in a number of applications. The
812 radium content of the paint varied from 0.2-5 MBq (0.005-0.12 mg) radium per gram
813 depending upon whether it was used in clocks, watches or instrument dials. Radium
814 was also used in some electronic valves and starting switches. The amount of radium
815 varies from hundreds of Bq in electronic valves to the order of tens of kBq in some
816 luminous applications.

817 Radium-226 has a high radiotoxicity because it is an alpha emitter that behaves like
818 calcium and concentrates in bone. Radium-226 has a half-life of 1600 years and its
819 decay chain includes eight radionuclides four of which are alpha emitters. The first
820 decay produces radon-222, a noble gas with a half-life of 3.6 days which may escape
821 from devices containing radium-226 and lead to inhalation doses. Facilities where
822 radium-containing waste is stored should be well ventilated and have means for
823 monitoring radon levels in the air. The likelihood of radioactive radon gas being
824 released from waste containing radium-226 and the potential dose to personnel
825 should be evaluated in assessing the suitability of packages for radium-containing
826 waste and the means of storage.

827 The management of more intense radium sources, such as radium needles and Ra-Be
828 neutron sources, is discussed in Annex B.

829 **Issues related to Smoke Alarms containing Americium-241**

830 Many domestic smoke alarms contain a less than 40 kBq americium-241. The
831 radiation source is americium-241 dioxide in a gold matrix covered by a silver foil.
832 The foil is thin enough to allow alpha emissions to enter the ionization chamber but
833 the short range of alpha particles in air ensures that alpha particles do not escape
834 from the smoke alarm. Even if the foil containing the radioactivity is removed from a
835 smoke alarm, the alpha particles do not penetrate the dead layer of human skin.
836 Americium-241 also emits a low energy gamma ray, but the gamma dose rate from a
837 domestic smoke alarm is low. The americium dioxide used in a smoke alarm is
838 extremely insoluble and, even if swallowed, would pass through the digestive system
839 and not be absorbed.

840 The Radiation Health Committee advised that from environmental and public health
841 perspectives, the disposal of small numbers of individual smoke alarms with
842 domestic rubbish does not represent any hazard (ARPANSA 2001). When significant
843 numbers of smoke alarms are collected together for bulk disposal, they should be
844 treated as radioactive waste. It may be acceptable in some jurisdictions to dispose of
845 significant numbers of smoke alarms in municipal land fills provided each smoke
846 alarm is accompanied by at least a specified amount of non-radioactive waste.

847 **Pretreatment**

848 The paint used in luminous devices can degrade and lead to radium contamination.
849 Items containing radium should be collected and stored in sealed containers to
850 control possible spread of contamination.

851 For items of historic value, consideration could be given to replacing the components
852 marked with the radioactive luminous paint with non-radioactive replicas. However,
853 there could be further contamination by radon progeny so all items should be
854 checked for any residual contamination before being released for general access.

855 The first step in managing items containing low levels of long-lived alpha emitters is
856 to determine the radioactivity in each item. In some cases, the items will be marked
857 at manufacture with the contained radioactivity. For these items containing small
858 amounts of long-lived radioactivity, it is reasonable to base their management on the
859 level of radioactivity marked on each item. If there is no record of the amount of
860 radioactivity on the item or in associated records, a gamma spectroscopy
861 measurement should be undertaken to determine the amount of contained
862 radioactivity. If there are a large number of similar items, enough representative
863 items should be measured to provide a good estimate of the total radioactivity.

864 Items containing more than 100 kBq of radium-226 or americium-241 should be
865 assessed to determine if they can safely be managed using the guidance in this Annex,
866 or if they should be managed using the guidance in Annex B as an item containing a
867 higher level of alpha emitters.

868 **Treatment**

869 The total volume of material to be managed as radioactive waste can sometimes be
870 minimised by separating the components containing the radioactivity from
871 components with no radioactivity. Any attempt to separate non-radioactive from
872 radioactive components should be undertaken in appropriate facilities with
873 monitoring for contamination. The foil containing the americium-241 may be able to
874 be safely removed from a smoke alarm, but this would result in more concentrated
875 radioactivity which may reduce disposal options.

876 Some items such as luminous antique watches can have value to collectors and need
877 to be secured against pilfering.

878 **Conditioning**

879 The small amount of radioactivity in each luminous item or smoke alarm means the
880 radioactivity can be considered to be dispersed in the package if a number of items
881 are encapsulated into a cement mortar or other matrix. Accidents, incidents or
882 intrusions that result in a broken, drilled or shattered package result in the
883 radioactivity being mixed with matrix material and the dose to an unintentional
884 intruder or bystander is likely to be much less than the public dose limit for a realistic
885 range of intrusion and accident scenarios and assuming that the waste is managed as
886 low level waste with appropriate access controls, mitigation procedures and barriers.

887 Items containing low levels of long-lived alpha emitters may be encapsulated in say
888 20 or 60 litre drums using a cement mortar. Such encapsulation provides security
889 and enables many items to be consolidated into one package. Encapsulation in a
890 small or medium size drum protects against the likelihood of contamination if the
891 radium paint deteriorates and limits release of radium. A 60 litre drum is small

892 enough for most future disposal options for low level waste, but might be too big for
893 borehole disposal (see Annex G).

894 The safety and security benefits of encapsulating items containing low levels of long-
895 lived alpha emitters in a cement mortar may justify undertaking this irreversible
896 treatment even if no disposal route is established and there are no waste acceptance
897 criteria.

898 The 60 litre drum may be encapsulated into a 205 litre drum with cement mortar
899 once a disposal facility is available, depending on the waste acceptance criteria for the
900 waste facility. The disadvantage of encapsulating the smaller drum into a 205 litre
901 drum is that the total weight of the 205 litre drum can exceed 500 kg, which may
902 require special handling equipment.

903 **Disposal**

904 The low level of radioactivity in each luminous device and smoke alarm means they
905 should be acceptable for disposal in a near-surface disposal facility.

906 **Annex B**

907

908 **Management of Devices containing Higher Levels of**
909 **Long-Lived Alpha Emitters (Radium Needles and Tubes,**
910 **Neutron Sources)**

911 **Issues Relating to Radium Needles and Tubes and Radium Neutron**
912 **Sources**

913 Prior to 1976, radium was commonly used in medicine in Australia for treatment of
914 cancer. For applications in medicine and industry, radium was usually encapsulated
915 in platinum, platinum-iridium and other alloys, and sometimes in gold. Such medical
916 items are commonly called needles or tubes, depending on their use. Typical
917 dimensions of needles are 1.7 mm diameter and 15-20 mm in length, and of tubes are
918 3 mm diameter and 20-25 mm in length. For special applications, medical sources
919 can have lengths of up to 60 mm and more. Typical dimensions of cell-filled needles
920 are 0.8 mm in diameter and 15 to 45 mm in length. [IAEA 1996]

921 The activity range for medical radium sources rarely exceeds 4 GBq (100 mg radium)
922 with the average source being about 200 MBq (5.6 mg radium) for needles and about
923 260 MBq (7 mg radium) for radium tubes. Over 90% of the radium needles and 78%
924 of the radium tubes are within the activity band of 40-400 MBq (1 to 10 mg). [IAEA
925 1996]

926 Radium-226 and its properties are described in Annex A.

927 Most radium sources were produced to earlier standards and leakage of radium
928 sources is highly possible. The chemical form of the radium needles and tubes makes
929 the spread of contamination from a leaking source a real and serious possibility.

930 Radium-226 was also used in neutron sources. About 30% of Ra/Be neutron sources
931 have a radium-226 radioactivity that exceeds 20 GBq (500 mg radium) and the
932 radioactivity of a small number of sources exceeds 40 GBq (1 g radium) of radium.

933 Some Ra/Be neutron sources were used for reactor start up operations. If the radium
934 is irradiated in a nuclear reactor, some of the target atoms are converted into
935 actinium-227 and thorium-228, both shorter lived alpha emitters, which can increase
936 the neutron yield by a factor up to 50 times.

937 All waste containing radium is a potential source of radon, a radioactive gas that can
938 be dispersed into the air of a storage facility. The likelihood of radioactive radon gas
939 being released from waste containing radium-226 and the potential dose to personnel
940 should be evaluated in assessing the suitability of packages for radium containing
941 waste and the means of storage.

942 **Pretreatment**

943 The first step in pretreatment is to gain information on the amount of radium and the
944 integrity of the source. Legacy radium needles and tubes are prone to leakage, so an
945 assessment should be made to determine whether to open any container, or whether
946 it is more appropriate to overpack. In general, if there is reasonable confidence that
947 the sources are not leaking, it is better to remove the needles or tubes from any
948 existing container so that all needles and tubes can be placed in a new capsule with

949 appropriate quality control. However, if there is a likelihood that the sources are
950 leaking it may be preferable to overpack.

951 Contamination control and contamination checks should be carried out at all stages
952 of pretreatment, treatment and conditioning. Precautions for damaged and leaking
953 sources include surface wipes for loose contamination, area monitors and personal
954 dosimeters, relevant to the radiation and contamination being handled and radiation
955 from that contamination.

956 Adequate ventilation, filtration systems and shielding should be in place to protect
957 personnel and the environment. Appropriate personal protection equipment is
958 important to prevent internal and external contamination. This equally applies to
959 conditioning and temporary storage. These precautions are particularly relevant to
960 sources for which there is not a complete set of records. Any lack of information may
961 increase the risk during the handling and conditioning operations.

962 Sources should be characterised by gamma spectroscopy to determine or verify their
963 total radioactivity. Shielding corrections for the source container and any packaging
964 might have to be estimated. Storage, transport and ultimately disposal will require a
965 documented estimate of the total radioactivity.

966 Neutron sources are often shielded by borated paraffin or other hydrocarbon. The
967 presence of this flammable shielding material of neutron sources can limit the use of
968 flame cutting and grinding tools for volume reduction purposes. Special
969 consideration should be given to the transport of Ra/Be sources which may require
970 additional shielding for neutrons.

971 **Treatment/Conditioning**

972 The conditioning of radium sources needs strict requirements and quality assurance
973 procedures to guarantee their safe storage for an extended period of many decades.

974 It is recommended that to achieve adequate containment of the radium and radon,
975 the spent radium needles and tubes should be enclosed in a leak-tight stainless steel
976 capsule. Preferably, the capsule should be sealed by welding. The method of source
977 encapsulation should take into account the following factors:

- 978 • the number of sources to be encapsulated;
- 979 • the size of sources;
- 980 • the activity of the sources; and
- 981 • the type of ionizing radiation (alpha, gamma, beta, neutrons, etc.).

982 The capsule should fit into a suitable radiation shield in order to minimize radiation
983 dose rates for storage and transportation.

984 Special radiological precautions should be taken when handling Ra/Be neutron
985 sources with activities greater than 1 GBq because of the significant neutron and
986 gamma dose rate.

987 In the Annex to IAEA-TECDOC-886 (IAEA 1996), the IAEA provides detailed
988 instructions for one method of encapsulating radium sources. In the IAEA method,
989 radium sources are placed in a leak tight stainless steel capsule that is welded shut or
990 a in a stainless steel capsule with a screw top and metal gasket seal. The sealed
991 capsule should have enough air space to ensure that the pressure rise from helium
992 generated in the decay of radium does not lead to excessive pressure build-up over

993 the life of the capsule. When sealed, the capsule should be tested for leak tightness
994 e.g. by using a vacuum bubble test.

995 Other encapsulation techniques may be used that meet the waste acceptance criteria
996 for disposal. The encapsulation in stainless steel capsules facilitates the retrieval of
997 the capsule when it is taken from storage for final disposal.

998 In the IAEA method (IAEA 1996), the capsules are placed inside a lead container for
999 shielding, and the lead container is placed in a cavity in a 205 litre mild steel drum
1000 with a concrete lining. In the case of neutron sources, hydrogenous material such as
1001 wax or high density polyethylene should also be considered. The concrete provides
1002 physical protection and security of the sources.

1003 Where practicable, lead should not be used in a package destined for disposal because
1004 lead is a toxic material and its presence might limit disposal options. Lead can be
1005 used for shielding so long as the capsule containing the radium is removed from the
1006 lead shield before disposal. The use of lead in a small number of packages may be
1007 acceptable if this avoids double handling of waste and provides operator protection.

1008 The design of the shielding package should take into account the following factors:

- 1009 • the total radioactivity of the sources to be stored in the package;
- 1010 • retrievability;
- 1011 • physical security;
- 1012 • radiation protection; and
- 1013 • storage period.

1014 For transport, it is advantageous if the capsules containing radium can be
1015 transported in Type A packages. Where practicable, the radioactivity of radium-226
1016 in a package should be limited to less than 3 GBq. Under the *Code of Practice for the*
1017 *Safe Transport of Radioactive Material* (ARPANSA 2008), a Type A package shall
1018 contain less than 200 GBq for a special form radium-226 and less than 3 GBq for
1019 other radium-226, provided that the only radioactivity in the package is the radium
1020 and the radium progeny nuclides. The limit of 200 GBq applies only if the source or
1021 package has a special form certificate. The special form certificates for most old
1022 sources are likely to be out of date and unlikely to be renewable.

1023 During interim storage it is advisable to keep the welded capsule containing the
1024 radium sources retrievable, to avoid prejudicing their further management. In order
1025 to ensure physical security of the sources, the shielding package should be closed by a
1026 locking device and have a gross weight of at least 100 kg. The shielding package
1027 should limit radiation exposure and be suitable for storage for periods of many
1028 decades.

1029 **Disposal**

1030 Waste items containing higher levels of long-lived alpha emitters (including radium
1031 needles and tubes and neutron sources) are an intermediate level radioactive waste.
1032 The combination of long half-life and high radioactivity concentration is likely to
1033 make these items unsuitable for near-surface disposal. Hence waste containing
1034 higher levels of long-lived alpha emitters is likely to need storage until a deep
1035 borehole or other geological waste disposal facility is established.

1036 As discussed in Annex G, keeping package diameters to 100 mm or less gives
1037 confidence that the waste will be able to be disposed of in almost any borehole
1038 facility.

1039 **Annex C**

1040

1041 **Management of Disused Sealed Sources of Low**
1042 **Radioactivity (<100MBq) and Gaseous Tritium Light**
1043 **Sources**

1044 **Issues Relating to Low Radioactivity Disused Sealed Sources**

1045 Disused sealed sources of low radioactivity present fewer management problems than
1046 high radioactivity sources because they have a low contact dose rate and many are
1047 suitable for near-surface disposal.

1048 The radioactivity material in low radioactivity sources is usually encased in plastic or
1049 metal. The source is designed to contain the radioactivity for the design purpose and
1050 certified life of the source. To ensure the source is not damaged, low activity sealed
1051 sources should not be subjected to compaction, shredding or incineration, which may
1052 be acceptable methods of treatment/conditioning for other waste types.

1053 Even though most sealed sources with radioactivity less than 100 MBq do not pose a
1054 significant risk to individuals, society and the environment, measures should be
1055 established to deter unauthorised access to stored disused sources and the presence
1056 of the source verified at set intervals.

1057 The preferred options for managing low activity disused sources are by return to the
1058 manufacturer, or reuse. If return to manufacturer or reuse are not viable options,
1059 then the sources should be managed as radioactive waste.

1060 **Pretreatment**

1061 Low radioactivity sources should be segregated to facilitate storage and disposal. The
1062 degree of segregation depends on the number and types of sources. At a minimum,
1063 sources should be segregated into short-lived, medium-lived and long-lived sources
1064 using the criteria discussed in Section 4.3.

1065 If a large number of sources is being managed, it may be advantageous to further
1066 segregate the sources based on the radionuclides present and the type of source.

1067 Many disused short-lived sources can be managed by storage to allow the radioactive
1068 material to decay to below the exemption level, when they no longer need to be
1069 managed as radioactive waste. A period of 10 half-lives reduces the level of
1070 radioactivity of any source by a factor of 1000. For some short-lived sources, a period
1071 of 10 half-lives will allow the source to decay to insignificance, but a longer period
1072 may be required for more intense sources.

1073 If decay to exemption levels is not viable, the source will need to be stored until a
1074 disposal route is available. Most low activity (<100 MBq) disused sources are likely
1075 to meet the waste acceptance criteria for near-surface disposal facilities.

1076 **Treatment**

1077 It is usually preferable to remove the radioactive sources from gauges and
1078 instruments to minimise the quantity of material to be managed as radioactive waste.
1079 Consideration should be given to keeping the source in any source housing and
1080 shielding for ease of handling the source safely.

1081 Sources should initially be consolidated into stainless steel containers that are
1082 marked with a radioactivity symbol and stored in a secure location. A label on the
1083 container should indicate container number, the radioactivity contained, the
1084 maximum contact dose rate and the reference date(s) for the radioactivity and the
1085 dose rate.

1086 To facilitate transport to and from storage locations, it is preferable to consolidate
1087 material in certified Type A containers for transport or in containers that fit into
1088 certified Type A containers.

1089 **Conditioning**

1090 The extent of conditioning depends on the likely disposal route. If there is
1091 uncertainty as to whether a group of sealed sources will be accepted for disposal, the
1092 sources should not be irretrievably conditioned until appropriate waste acceptance
1093 criteria are issued for an established repository unless there are clear safety or
1094 security benefits. Guidance on this issue is provided in Section 4.4.

1095 Sources should be stored in containers made from stainless steel or other material
1096 appropriate to the expected period of storage. For small sources, the container could
1097 be stored in a concrete lined drum to provide shielding. The container should be
1098 retrievable from the concrete lined drum. See discussion in Annex B on storage
1099 options for radium needles.

1100 Larger containers could be backfilled with a grout or other matrix, but it would be
1101 preferable not to backfill until it is clear what is required by the repository waste
1102 acceptance criteria.

1103 **Disposal**

1104 A near-surface repository may be licensed to accept sealed sources of particular
1105 radionuclides and below a specified radioactivity level. The limits on low
1106 radioactivity sources at a disposal facility should be based on the post closure safety
1107 case submitted in support of the disposal facility licence and the licence conditions
1108 imposed by the regulator. Annex G discusses generic waste acceptance criteria where
1109 there is no established waste disposal facility.

1110 Most low radioactivity (<100 MBq) disused sources are likely to be acceptable in a
1111 near-surface disposal repository. Also likely to be accepted are short-lived and
1112 medium-lived disused sources that will decay to insignificant levels within the
1113 institutional control period of the repository. Medium-lived sources of higher
1114 radioactivity and long-lived sources are likely to require deeper disposal, such as a
1115 deeper borehole or other geological facility.

1116 **Annex D**

1117

1118 **Management of Disused Sealed Sources of Higher**
1119 **Radioactivity (>100MBq)**

1120 **Issues Relating to Higher Radioactivity Disused Sealed Sources**

1121 Disused sealed sources of higher activity present management problems because of
1122 the high radioactivity content and the usually high radiation dose rate when the
1123 sources are not shielded.

1124 The radioactivity in some sealed sources can be in a dispersible powder form. The
1125 source is designed to be a robust item for the certified life of the source and the
1126 design purpose of the source. To ensure the source is not damaged, sealed sources
1127 should not be subjected to compaction, shredding or incineration, which may be
1128 acceptable for other waste types.

1129 The radioactivity level in some sources is high enough to pose a significant risk to
1130 individuals, society and the environment. This places particular requirements on the
1131 security of these sources. Security requirements for high radioactivity sealed sources
1132 are provided in the *Code of Practice for the Security of Radioactive Sources*
1133 (ARPANSA 2007).

1134 Sources containing higher levels of radioactivity are usually treated as a special case
1135 when it comes to disposal. Due to the higher radioactivity concentrations in these
1136 sources, the safety assessment for disposal of sealed sources may require assessment
1137 of intrusion scenarios that are different from those for more dispersed radioactive
1138 waste. The waste acceptance criteria for a disposal facility are likely to have specific
1139 requirements for sealed sources. As far as possible, irreversible treatments should be
1140 avoided in processing higher activity sealed sources until clear waste acceptance
1141 criteria are developed.

1142 **Pretreatment**

1143 Pretreatment includes collection of waste, segregation of waste and waste
1144 decontamination. The purpose of pretreatment is to reduce the amount of waste
1145 requiring further processing and disposal or to alter the packaging of form to
1146 facilitate further treatment.

1147 Disused sealed sources should be collected and the records pertaining to each waste
1148 item examined. Records should include details of the following:

- 1149 • the source container identification number;
1150 • the radionuclide(s) present;
1151 • the activity of the source and date of measurement;
1152 • identification of the area in which the source was utilised;
1153 • the surface dose rate and the date of measurement;
1154 • the mass and volume of the package; and
1155 • the responsible person.

1156 If any of these details are not available then they should be determined before
1157 proceeding with further waste processing.

1158 Source certification documentation should be reviewed and the originals stored in a
1159 secure location. The certification period on the source documentation should be
1160 checked and a renewal sought from the regulator before the certification period
1161 expires. Transport of sealed sources becomes more difficult if the special form
1162 certification has lapsed.

1163 Disused sealed sources that can be reused or returned to the manufacturer should be
1164 dealt with at this stage removing the need for their further management as
1165 radioactive waste. For reuse to be a viable option, the source certification should be
1166 current for the expected period of future use. Otherwise, return of disused sealed
1167 sources to their manufacturer is the preferred option. The manufacturer has the
1168 capability to assess whether the source or contained radioactivity can be recycled,
1169 disassembled or transferred to waste and the personnel and facilities to disassemble
1170 and recertify sources if appropriate.

1171 If return to manufacturer or reuse are not options, then the sources need to be
1172 managed as radioactive waste.

1173 Sealed sources of higher activity should be segregated on the basis of half-life to
1174 facilitate appropriate management. A possible segregation would be based in the
1175 definition of short-lived, medium-lived and long-lived radionuclides discussed in
1176 Section 4.3.

1177 Many short-lived sources can be managed by storage to allow decay. They can also
1178 potentially be disposed of to near-surface disposal facilities because their
1179 radioactivity decays to insignificant levels during the institutional control period of
1180 the facility. After a period of 10 half-lives, i.e 53 years for cobalt-60, the radioactivity
1181 reduces by a factor of 1000. For some high radioactivity cobalt-60 sources, 20 half-
1182 lives or more would be required for the level of radioactivity to reduce to insignificant
1183 levels.

1184 Medium-lived sources can take many hundreds of years to decay to insignificant
1185 levels. Hence their disposal options depend on the particular radionuclide(s) in the
1186 source. Only low level medium-lived sources are suitable for disposal in a near-
1187 surface repository. In general, it is more appropriate to dispose of medium-lived
1188 sources of higher activity in a geological facility or deep borehole facility.

1189 Long-lived sources of higher activity need to be disposed of in a geological facility or
1190 deep borehole facility

1191 Disused sources can leak and potentially lead to the inhalation of, or contamination
1192 with, toxic materials. Consequently, general and industrial safety rules should be
1193 observed whenever disused sources are handled. Adequate ventilation and filtration
1194 systems should be in place to protect personnel and the environment.

1195 **Security**

1196 The *Code of Practice for the Security of Radioactive Sources* (ARPANSA 2007) (“the
1197 Security Code”) and the IAEA Code of Conduct on the Safety and Security of
1198 Radioactive Sources (2004) place special requirements on radioactive sources that
1199 pose a significant risk to individuals, society and the environment. The Security Code
1200 applies to sources in use as well as disused sources that appear as waste and places
1201 specific requirements on the management of sources containing higher levels of
1202 radioactivity.

1203 The Security Code defines categories for sources that could potentially cause severe
1204 health effects. When a source is declared waste, its category should be reassessed
1205 after taking into account any radioactive decay. Security arrangements implemented
1206 for the disused source should correspond to the source category and the security
1207 group of the source.

1208 **Source and Container Integrity**

1209 Sources should be checked for leakage of radioactive contents. Source leakage is
1210 usually assessed by performing wipe tests. The type of test undertaken is dependent
1211 upon the radionuclide and the activity of the source. Leak checking should be
1212 undertaken by competent personnel from an organisation that has been approved by
1213 the regulator. If the source is found to be leaking, the source should be overpacked in
1214 a container approved for storage while the future course of action is assessed and
1215 approved.

1216 Removal of a leaking source from any housing or shielding will require monitoring of
1217 the removed material. Material found to be contaminated should be decontaminated
1218 or treated as radioactive waste.

1219 For sources that are not leaking, consideration should be given to their potential
1220 reuse. If a source is reusable, it should be transferred to the new user or placed into
1221 storage for future use. If the source can not be reused then the source should be
1222 returned to the manufacturer if possible. Disused sources that are not reusable and
1223 cannot be returned to the manufacturer should be treated as waste.

1224 The source management strategy should be risk-based and consistent with national
1225 and international guidance. The management strategy will take into account the
1226 radionuclide half-life, the source activity, the types of radiation emitted, the
1227 characteristics of the source design and form of the radioactive substance.

1228 Many higher activity sealed sources come with a primary container which provides
1229 shielding and a locking system to secure the source. In the short term, the disused
1230 source should be kept in this primary container to provide shielding and security.
1231 The state of the primary container should be assessed as part of the source
1232 characterisation and a decision made whether to keep the source in the primary
1233 container or to design and construct a replacement container.

1234 **Treatment**

1235 The first stage of treatment is volume reduction by removal of extraneous parts of the
1236 source housing and instrument components. The volume reduction should be
1237 performed only to the extent that maintains an adequate level of safety and security
1238 for the source being treated. A means of locking the source in its housing should be
1239 kept or new locking system provided. The extraneous material removed should be
1240 checked for contamination and disposed of appropriately.

1241 The next stage of volume reduction is removal of the sources from the original
1242 devices and grouping them together with similar sources for conditioning. This can
1243 allow the use of standard storage containers and shielding, as well as optimising
1244 safety and security measures. Source removal requires dedicated facilities and
1245 experienced personnel. Damaged and leaking sources will require extra precautions
1246 as well as specialised equipment providing both shielding and containment. Care
1247 should be taken not to weaken or damage the source.

1248 Waste packages for disused sources should confine the radioactivity in the source
1249 both under normal conditions and under accident conditions. The storage container
1250 should shield radiation to allow for appropriate handling, protect the source against
1251 mechanical and corrosion effects and prevent unauthorised access to the source.

1252 A source holder or source containment device should be selected that is appropriate
1253 to the form and type of the source it is to contain. For example, some caesium
1254 sources are made of caesium chloride powder which can corrode a stainless steel
1255 capsule from the inside in the long-term. Low activity caesium-137 sources are now
1256 usually prepared in ceramic form, making the radionuclide less dispersible, the
1257 ceramic form is not suitable for high activity caesium-137 sources.

1258 Wherever possible, a number of sources should be consolidated into one container to
1259 minimise the volume of waste for disposal. The number and activity of sources for
1260 consolidation should be carefully considered to ensure the limits for transportation as
1261 an acceptable category are not exceeded. If possible, the total activity in a package
1262 should be kept within the limits for transport as a Type A package. Limits for the
1263 amount of radioactivity in a Type A container for different radionuclides are specified
1264 in the *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA
1265 2008).

1266 **Conditioning**

1267 The conditioning process for disused sealed sources normally involves immobilising
1268 the waste in a suitable matrix, containing the immobilised waste in a suitable
1269 container and providing any additional packaging. The purpose of the conditioning
1270 process is to produce a packaged waste suitable for the selected disposal option and
1271 which meets requirements for waste handling, storage and transport.

1272 Sealed sources of higher radioactivity should not be irreversibly conditioned until
1273 waste acceptance criteria are available for a disposal facility. This usually means that
1274 the source should not be immobilised in a matrix until there is a disposal facility
1275 available to accept the waste. However, safety considerations may warrant some
1276 immobilisation to provide adequate safety during storage (see also discussion in
1277 Section 4.4 on undertaking irretrievable treatments).

1278 The conditioning matrix should ensure low leachability of radionuclides from the
1279 waste form. The matrix should also be compatible with both the waste and the
1280 container.

1281 Sources can be encapsulated into welded or sealed steel capsules, stainless steel
1282 drums or their original lead pot to facilitate future management. Free space within
1283 containers should be kept to a minimum to reduce the possibility of collapsing voids
1284 and ensure structural stability should the waste packages themselves be relied upon
1285 for maintaining the structure of the disposal facility.

1286 **Disposal**

1287 Sealed sources of higher activity present a particular problem for disposal because the
1288 radioactivity in the source exists in a very concentrated form and the source might
1289 maintain its integrity beyond the institutional period of a repository.

1290 Short-lived sources containing even high levels of radioactivity could be suitable for
1291 near-surface disposal if they decay to insignificant levels during the institutional
1292 control period of the disposal facility. Very short-lived sources could be stored until
1293 the level of radioactivity is less than exemption levels.

1294 Medium and long-lived disused sources containing higher levels of radioactivity are
1295 an intermediate level radioactive waste unsuitable for near-surface disposal. Much of
1296 this waste will have to be stored until a geological waste disposal facility, such as a
1297 borehole facility, is established.

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Annex E

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Management of Laboratory and Medical Waste

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Issues Relating to Laboratory and Medical Waste

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Radioactive laboratory and medical waste is very diverse; it can contain a wide range of radionuclides with a wide range of activities in many different forms. A good understanding of the generation process usually provides knowledge of the radionuclides present and their concentrations. If knowledge of the generation process is poor, then the waste should be characterised to provide the information required for waste management.

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Care should be taken to segregate waste that may contain radioactivity from non-radioactive waste to minimise the amount of radioactive waste. Measurements should be undertaken on all waste that may contain radioactivity so that waste containing radionuclides below regulatory exemption limits can be treated as non-radioactive waste.

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Waste that exceeds the regulatory exemption limits should be assessed to determine if it can be disposed of to the sewer or to a municipal tip. The requirements and limits for discharge of very low level waste to the sewer or disposal of small amounts of low level waste to municipal tips are proposed to be covered in Schedule 8 of the National Directory for Radiation Protection.

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For waste containing short-lived radionuclides, it may be feasible to store the material to allow the radioactivity to decay to activities such that they meet proposed requirements and limits in Schedule 8 of the National Directory for Radiation Protection. Radioactive waste held for decay should be kept in secure stores and each container should be clearly labelled with a description of the radioactive contents, the activity when stored, the anticipated date when it may be released from the store and the name of the person responsible for placing it in the store. An accurate inventory of all containers and their contents in the store at any time should be maintained.

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Waste from different processes may contain different radionuclides and have different concentrations. The different wastes should be segregated if segregation provides a significant benefit in optimising waste management of the different waste types. Segregation is most important if an organisation deals with both short-lived and long-lived radionuclides, or if it deals with both beta/gamma and alpha emitters. Waste containing or possibly containing alpha emitters should be segregated from waste with no alpha emitters, because disposal limits for alpha emitters are much more restrictive than limits for beta/gamma emitters. The amount of waste generated containing alpha emitters should be minimised.

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The low specific radioactive concentration of much laboratory and medical waste means that most will be acceptable in a near-surface repository and the generic waste acceptance criteria described in Annex G are likely to provide a reasonable basis for treating and conditioning laboratory waste.

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The US National Council on Radiation Protection and Measurements has issued a report on management techniques to minimize off-site disposal of low-level radioactive waste (NRC Report No 143, 2003). This report provides additional guidance on minimising and treating many types of laboratory wastes.

1343 **Pretreatment**

1344 The first pretreatment operation should be to collect the radioactive waste and
1345 segregate items as appropriate on the basis of radiological, physical, chemical and
1346 pathogenic properties. Waste containing predominantly short-lived radionuclides
1347 should not be mixed with long-lived waste.

1348 Knowledge of the processes generating the waste may provide adequate knowledge of
1349 the radioactivity and radionuclides in the waste. If this is not sufficient the waste
1350 should be characterised. The initial characterisation could be based on knowledge of
1351 the process generating the waste and the radionuclides involved in the process,
1352 combined with dose rate and perhaps preliminary gamma spectroscopy. This initial
1353 characterisation could provide enough information to allow disposal or storage
1354 options to be determined.

1355 Wastes of different types and radioactivity concentrations (or total radioactivity in
1356 the case of sources) may be segregated to facilitate waste management according to
1357 the overall waste management strategy and the available facilities.

1358 Considerations for segregation include:

- 1359 (a) Radioactivity concentration: higher radioactivity waste separated from lower
1360 radioactivity waste;
- 1361 (b) Half-life: waste containing long-lived alpha emitters should be separated from
1362 waste with no alpha emitters;
- 1363 (c) Form: solid, gaseous and liquid wastes are treated separately;
- 1364 (d) Combustible or non-combustible;
- 1365 (e) Compressible or non-compressible;
- 1366 (f) Metallic or non-metallic;
- 1367 (g) Fixed or non-fixed surface contamination;
- 1368 (h) Materials and objects that are pyrophoric, explosive, chemically reactive or
1369 otherwise hazardous;
- 1370 (i) Items containing free liquids or pressurized gases;
- 1371 (j) Waste containing infectious agents or is regulated as medical waste; and
- 1372 (k) Animal carcasses and putrescibles materials.

1373 Segregation is only worthwhile if the segregated wastes will be treated differently as
1374 they move through the waste management steps to disposal or if waste acceptance
1375 criteria for disposal are likely to be different.

1376 A more definitive characterisation should be undertaken prior to any treatment and
1377 or conditioning. This characterisation should be sufficiently comprehensive to
1378 provide adequate information for assessing treatment steps and demonstrating
1379 compliance with the appropriate transport code and disposal waste acceptance
1380 criteria.

1381 If all radionuclides in a waste package have half-lives less than about a year,
1382 consideration should be given to storing the waste in an approved storage facility
1383 until radioactivity has decayed to exemption levels.

1384 Other actions undertaken in pretreatment could be to adjust the characteristics of the
1385 waste to make it more amenable to further processing and to reduce or eliminate
1386 certain hazards posed by the waste owing to its radiological, physical, chemical or
1387 pathogenic properties.

1388 Larger items with limited contamination can sometimes be decontaminated to reduce
1389 the volume of waste. Mechanical, chemical and electrochemical methods can be used
1390 to remove surface contamination from a large item. The decontamination process
1391 should be planned to ensure that the characteristics of the secondary waste are
1392 compatible with the requirements for future management. The assessment as to
1393 whether to undertake decontamination should take into account the total amount of
1394 waste that will be generated by the decontamination (including any plastic sheeting,
1395 cleaning equipment, and liquid waste) and doses to workers from the
1396 decontamination.

1397 Some items can be disassembled to remove a smaller radioactive components or
1398 contaminated items from a larger volume of non-radioactive material.

1399 Waste acceptance criteria for disposal are likely to contain exclusions for PCBs,
1400 hazardous materials, infectious waste, putrescible waste and explosive materials; and
1401 limits on some combustible materials, lead and lead compounds, surfactants,
1402 flammable liquids, pressurised gases, chelating agents, organic liquids and free
1403 liquids. Estimates of these and similar hazardous and/or toxic components should be
1404 determined from process knowledge or direct measurement, and the information
1405 documented and stored with the inventory so that it is available when the waste is
1406 sent for storage and disposal.

1407 In the hospital environment, bed linen which may be contaminated with radioactive
1408 materials should remain segregated from other linen and laundered separately. Any
1409 linen and similar material for disposal which is also radioactive should remain
1410 segregated from non-active waste and be appropriately disposed of as radioactive
1411 waste.

1412 **Liquid waste**

1413 Liquid radioactive waste can be generated in laboratory or medical applications of
1414 radioactive materials. Liquid waste potentially containing radioactivity above
1415 exemption levels should be collected in holding tanks.

1416 Where liquid radioactive waste containing radioactivity at a level that may
1417 conceivably exceed those which may be discharged directly to the sewers is regularly
1418 produced in a laboratory, sinks should be connected to a holding or delay tank system
1419 and these sinks should be restricted to uses involving radioactive materials. Where
1420 the volume of liquid radioactive waste is small, a labelled screw top container in the
1421 working area may be adequate.

1422 Toilets used by patients being treated with radioiodine should be clearly marked and
1423 only used by those patients. The effluent from these toilets should be connected to a
1424 holding tank system and be monitored before discharge to the sewerage system.

1425 To facilitate subsequent processing, it can be advantageous to install individual
1426 holding tanks on all source lines so that any waste with higher than expected levels of
1427 radioactivity can be collected and treated separately before it is mixed with lower
1428 radioactivity waste.

1429 Holding tanks are usually constructed in sets of two or more so that one may be
1430 filling while the contents of a full one is being sampled, analysed and discharged.
1431 Tanks for temporarily holding liquid waste should:

- 1432 (a) be leak-free;
- 1433 (b) have visual indicators of the volume of the contents and warning
1434 devices to indicate when the tank is almost full;
- 1435 (c) be enclosed in a secondary enclosure of sufficient volume to hold the
1436 contents if at any time there should be a loss of tank contents;
- 1437 (d) have facilities which allow easy withdrawal of representative samples;
- 1438 (e) have a means allow inspection of build-up of deposits on the base or
1439 sides and to allow access for clearing (incorporation of mechanical
1440 agitators may reduce the incidence of deposits); and
- 1441 (f) have appropriate sanitary control if the tank holds human or animal
1442 wastes.

1443 Liquid waste should be characterised on the basis of process knowledge and
1444 preliminary measurement. Mixing liquid waste streams should be limited to those
1445 streams that are radiologically similar and chemically compatible. It is usually
1446 preferable to treat a small amount of more concentrated liquid waste rather than
1447 treat the large volume created when the more concentrated liquid is mixed into a
1448 larger volume of liquid with low or very low levels of radioactivity. Aqueous liquid
1449 waste streams should not be mixed with organic liquid waste. Organic liquid waste
1450 may be flammable, and its collection and storage should incorporate provisions for
1451 adequate ventilation and fire protection.

1452 The non-radiological characteristics of liquid waste should be assessed to determine
1453 if there are other hazardous components in the waste that limit the management
1454 options for the waste.

1455 Limited quantities of liquids with low concentrations of radioactivity may be suitable
1456 for discharge to the sewer under the requirements and limits for discharge of
1457 radioactive waste by the user, proposed to be included in Schedule 8 of the National
1458 Directory for Radiation Protection.

1459 **Treatment**

1460 Treatment of laboratory waste may include:

- 1461 (a) Volume reduction by compaction of solid waste, by disassembly of bulky waste
1462 components or equipment, and by incineration of combustible waste;
- 1463 (b) Removal of radionuclides from liquid and gaseous waste streams by
1464 evaporation or ion exchange for liquid waste streams and filtration of gaseous
1465 waste streams; and
- 1466 (c) Change of form or composition by chemical processes such as precipitation,
1467 flocculation and acid digestion as well as chemical and thermal oxidation.

1468 In general, treatment of radioactive waste requires approval from the regulator before
1469 any treatment or packaging is undertaken. In some cases, this could already be
1470 included under an existing licence; in others, specific approval will be required.

1471 Compaction can be an effective method for reducing the volume of a compressible
1472 waste. The characteristics of the material to be compacted and the desired volume

1473 reduction should be well defined and controlled. Issues to be taken into
1474 consideration in assessing the safety of compaction should include:

- 1475 (a) Possible release of volatile radionuclides and other airborne radioactive
1476 contaminants as gases or dust;
- 1477 (b) Possible release of contaminated liquid during compaction;
- 1478 (c) Chemical reactivity of the material during and after compaction; and
- 1479 (d) Potential fire and explosion hazards due to pyrophoric or explosive materials or
1480 pressurized components.

1481 Disassembly and other size reduction techniques may be used for waste that is bulky
1482 or oversized in relation to the intended processing. Processes for size reduction can
1483 include sawing, hydraulic shearing, abrasive cutting, plasma arc cutting and cutting
1484 with high temperature flames. Preventing the spread of particulate contamination
1485 should be considered in the choice of method and in the operation of the equipment.

1486 Combustible solid waste and radioactive organic liquids may be incinerated, calcined
1487 or treated with other advanced oxidation technique suitable for reducing the volume
1488 of waste and producing a stable waste form. After incineration, calcination or
1489 advanced oxidation, radionuclides from the waste are distributed between the
1490 residue, the products from cleaning the exhaust gases and any stack discharges. The
1491 distribution of radioactivity and other combustion products to each of these waste
1492 streams should be assessed for all normal and abnormal conditions. Any proposal for
1493 incineration, calcination or other advanced oxidation technique should be referred to
1494 the regulator for approval.

1495 If the radioactive waste contains fissile material, the potential for criticality should be
1496 evaluated and eliminated by means of appropriate design features and administrative
1497 controls.

1498 Used filters from treating gases at facilities using radioactivity are a solid radioactive
1499 waste. Care should be taken to ensure that radioactive materials trapped on filters
1500 are not dispersed during handling the filters or the subsequent treatment of filters.
1501 Many filters will have only low levels of radioactivity and it may be worth assessing
1502 whether the level of radioactivity is below the exemption levels given in the National
1503 Directory for Radiation Protection (ARPANSA 2004). Filters containing radioactivity
1504 can usually be compacted to reduce the volume of radioactive waste to be managed.

1505 For any waste management process that potentially leads to airborne emissions, stack
1506 discharges should be monitored by appropriate technologies to ensure that the
1507 concentrations and amounts of radionuclides discharged are within the limits
1508 specified by the regulatory body and are consistent with the parameters modelled in
1509 the safety assessment.

1510 **Treatment of Liquids**

1511 All liquid radioactive waste should be converted to solid form as soon as practicable.
1512 Solid waste is easier to store safely and a repository for waste disposal is likely to only
1513 accept solid waste with limits on the amount of free liquid.

1514 Treatment of organic liquid waste, e. g. contaminated oil depends on the organic
1515 liquid involved so relevant advice should be sought to develop an appropriate
1516 treatment.

1517 Methods for converting radioactive aqueous liquid waste to a solid form include:

- 1518 (a) chemical precipitation, for example precipitating the radioactive component as
1519 hydroxide by raising pH;
- 1520 (b) evaporation of liquid and management of the residue as solid radioactive waste;
- 1521 (c) incorporation into a matrix, e.g. added to a sand cement mortar, bitumen
1522 polymer, ceramics or glass;
- 1523 (d) adsorption of radioactivity onto a solid, e.g. alum followed by centrifuging to
1524 separate the solids from the liquid;
- 1525 (e) the use of ion exchange resin; and
- 1526 (f) filtration, ultrafiltration and reverse osmosis.

1527 Chelating agents, organic liquids or oil and salt content in liquid waste may also be of
1528 concern in some conditioning processes.

1529 Animal carcass waste might be incinerated or treated with lime and absorbent.
1530 Specific absorbents are available for dealing with biological material, and the specific
1531 instructions should be followed.

1532 **Conditioning**

1533 Conditioning laboratory waste may include the conversion of the waste to a solid
1534 waste form, enclosure of the waste in containers, and, if necessary, provision of an
1535 overpack. Conditioning could also be encapsulation of contaminated items in an
1536 inert matrix, such as a cement or mortar.

1537 The 20 litre, 60 litre and 205 litre steel drums are the preferred package sizes for
1538 laboratory radioactive waste. Galvanised or stainless steel drums have greater
1539 resistance to corrosion and may be preferred. A safety assessment should be
1540 performed to ensure that the drum selected is appropriate for the particular waste
1541 type. Other sized packages or type of package should be used if the safety assessment
1542 demonstrates a significant advantage in doing so. A generator producing small
1543 amount of radioactive waste might use smaller packages, but the smaller packages
1544 selected should be able to be packed into larger drums for ease of subsequent
1545 handling. If larger packages are indicated future transport and handling
1546 requirements should be considered, before deciding to use larger packages.
1547 Consideration should be given to cutting larger items to fit into a 205 litre drum.

1548 The dose rate on the outside of the package containing radioactive waste should be
1549 measured to ensure the package is suitable for the storage facility and the proposed
1550 mode of transport. Some waste may need to be encapsulated in cement mortar to
1551 reduce the contact dose rate on the outside of the package. Alternatively, additional
1552 temporary shielding and control procedures could be used to control access to areas
1553 with higher dose rates.

1554 Waste packages produced by conditioning should satisfy the acceptance criteria for
1555 transport, storage and disposal. To the extent practicable, conditioning of radioactive
1556 waste should produce a waste package with the following characteristics and
1557 properties:

- 1558 (a) Physical and chemical properties of the waste are compatible with any matrix
1559 materials and the container;
- 1560 (b) Low voidage;
- 1561 (c) Low permeability and leachability;

- 1562 (d) Structural stability;
- 1563 (e) Chemical, thermal, structural, mechanical and radiation stability will be
1564 maintained for the required period of time;
- 1565 (f) Resistant to chemical substances and organisms;
- 1566 (g) Suitable for retrieval at the end of the storage period;
- 1567 (h) Suitable for transport to and handling at a disposal facility; and
- 1568 (i) Meets waste acceptance criteria of disposal facility, or if the disposal facility is
1569 not yet established, meets the generic waste acceptance criteria in the *Code of*
1570 *Practice for Near-Surface Disposal of Radioactive Waste in Australia*
1571 (NHMRC 1992).

1572 Some materials require specific assessment before being encapsulated in concrete.
1573 Aluminium, magnesium and zirconium are known to react with the alkaline water of
1574 a cement slurry or water diffused from a concrete matrix, to produce hydrogen.

1575 The container may also need to provide radiation shielding. The selection of
1576 materials for the container and its outer surface finish should consider the ease of
1577 decontamination. An additional container or an overpack may be needed to meet the
1578 acceptance criteria if the container does not meet the relevant acceptance criteria for
1579 transport, storage or disposal. Any such package should be designed to maintain
1580 integrity and containment of the radioactivity for an extended period of storage if
1581 there could be a significant delay before an acceptable disposal route becomes
1582 available.

1583 **Disposal**

1584 Most laboratory radioactive wastes have a sufficiently low radionuclide concentration
1585 to be accepted at a near-surface disposal facility.

1586 **Annex F**

1587

1588 **Management of Residues from Industrial Processing and**
1589 **Waste from Remediation of Contaminated Sites**

1590 **Issues related to Management of Residues from Industrial Processing**

1591 Industrial processing can produce large quantities of residues containing
1592 radioactivity, mainly low levels of naturally occurring radioactive materials (NORM)
1593 such as uranium, thorium and radium and their progeny. The radioactivity in bulk
1594 waste is usually distributed uniformly through the waste and the concentration of
1595 radioactivity is usually low.

1596 Types of bulk waste that can include radioactivity include (Cooper 2004):

1597 (a) scale from pipes and valves in the oil and gas industry;

1598 (b) waste from the mineral sands processing;

1599 (c) waste from titanium paint production; and

1600 (d) waste from the phosphate industry.

1601 This Annex does not cover the management of radioactive waste from mineral
1602 processing where that waste is disposed of at a mine site and is covered by the *Code*
1603 *of Practice and Safety Guide for Radiation Protection and Radioactive Waste*
1604 *Management in Mining and Mineral Processing* (ARPANSA 2005) (“the Mining
1605 Code”). The Mining Code addresses the control of occupational and public radiation
1606 exposures in the mining and mineral processing industries, and for the management
1607 of radioactive waste generated in those industries. The radioactive waste from the
1608 mining and processing of uranium ores, thorium ores and mineral sands are covered
1609 by the Mining Code, but it may also be applied to other mining and operations where
1610 the wastes contain radionuclides at a level that may cause harm to humans or to the
1611 environment.

1612 The National Directory for Radiation Protection (ARPANSA 2004) specifies the
1613 criteria to exempt radioactive material or practices from notification, registration and
1614 licensing. Usually the large bulk of residues from industrial processing and waste
1615 from remediation of contaminated sites means that the contained radioactivity will
1616 exceed the limit on total radioactivity quantity prescribed in Schedule 4 of the
1617 Directory. However the Directory also allows material to be exempted if the
1618 radioactive material causes an annual effective dose to an individual member of the
1619 public of less than 10 μ Sv, and a collective effective dose to the critical group
1620 committed by one year of performance of the practice, as determined by the
1621 Authority, of less than 1 person Sv.

1622 **Issues related to Management of Waste from Remediation of**
1623 **Contaminated Sites**

1624 Large quantities of radioactive waste can be generated from the remediation of sites
1625 where radioactivity materials were used, where accidents involving radioactivity
1626 occurred or where industrial processing of naturally occurring radioactivity occurred.
1627 Most material collected during remediation is likely to have low levels or
1628 radioactivity. For site remediation, it is worthwhile characterising the material in situ
1629 before excavation to determine which material is contaminated with radioactivity
1630 above the exemption concentration limits given in the National Directory for

1631 Radiation Protection (ARPANSA 2004). There may be little advantage in excavating
1632 such material on the basis of its radioactivity unless that is a clearly identified
1633 exposure pathway that may cause harm to humans or the environment.

1634 The IAEA safety standard on remediation of areas contaminated by past activities
1635 and accidents (IAEA 2003) provides guidance on managing contaminated sites.

1636 **Pretreatment**

1637 The main step in pretreatment is to characterise the waste and determine the level of
1638 contained radioactivity, the radionuclides present, the presence of other toxic or
1639 hazardous substances, and the mobility of the radioactive species in the waste. The
1640 process generating the waste should be optimised to minimise the amount of waste
1641 containing radioactivity generated and ensure that the radioactivity in the waste is, as
1642 far as practicable, insoluble and not be mobile under storage and disposal conditions.
1643 If this cannot be achieved in the generating process, then the waste should be treated
1644 to reduce the mobility of the radioactive species.

1645 The appropriate storage container depends on the amount of waste generated.
1646 Medium amounts of waste could be stored in 205 litre drums. If drums are used,
1647 they should be completely filled to minimise voidage, and the waste compressed to
1648 reduce total volume should be considered. Waste to be placed in drums should be
1649 dry to reduce potential for corrosion of containers.

1650 If the waste occurs in large volumes, packing into drums is likely not to be
1651 appropriate. Rather, a disposal route should if possible be identified, such as a
1652 dedicated near-surface facility. A dedicated storage facility may be required to store
1653 the waste until it can be disposed. It may be advantageous to increase the density of
1654 the waste to reduce the total volume of waste and the number of shipments.

1655 **Treatment**

1656 The residues from industrial processing may need treatment to provide chemical
1657 stability, to remove free liquid and to provide structural stability. The need for
1658 structural stability depends on the method of disposal, which may require the waste
1659 to have a specified compressive and/or shear strength. For disposal, compressive
1660 strength is usually more important because potential for subsidence is a major
1661 concern for near-surface disposal facilities. Processes for treating residues from
1662 industrial processing and waste from site remediation should be assessed on a case
1663 by case basis for each different waste type.

1664 The waste acceptance criteria for disposal of bulk waste are likely to include a
1665 requirement for dry solid waste, minimal voidage and a compressive strength
1666 adequate to prevent subsidence.

1667 **Conditioning**

1668 The conditioning requirements for bulk waste need to be assessed case by case. Some
1669 bulk waste types may be conditioned by mixing with cement to form a structurally
1670 stable waste form. Cement produces a highly alkaline environment, and the impact
1671 of the alkalinity on the bulk waste should be assessed.

1672 **Disposal**

1673 Most bulk radioactive wastes that occur as residues from industrial processes or from
1674 remediation of contaminated sites have a sufficiently low radionuclide concentration

1675 to be accepted at a near-surface disposal facility, or a facility that meets the criteria
1676 for a near-surface activity. If there are large volumes of waste, consideration should
1677 be given to establishing such a facility should be close to the source of the waste, to
1678 minimise transport costs.

1679 In the oil and gas industry, consideration should be given to injecting scale
1680 contaminated with naturally occurring radioactivity down a well with recharge water
1681 where it can be demonstrated that there is no likelihood of the well ever being used
1682 again for extraction. This returns the radioactivity back to the geological depths from
1683 which it came and isolates the radioactivity from humans and the environment.

1684 **Annex G**

1685

1686 **Generic Waste Acceptance Criteria for Disposal of**
1687 **Radioactive Waste**

1688 **Near-Surface Disposal**

1689 Radioactive waste that is acceptable for disposal in a near-surface repository should
1690 conform to the requirements of Categories A, B and C in the *Code of Practice for the*
1691 *Near-Surface Disposal of Radioactive Waste in Australia* (NHMRC 1992).
1692 Concentration limits for the different categories are given in the Appendix to the
1693 Code for a near-surface repository at an arid remote site for a 100 and a 200 year
1694 institutional control period. It would be reasonable to assume that a near-surface
1695 repository in an arid remote site in Australia would accept waste that meets the
1696 concentration limits provided in the Near-Surface Disposal Code for a repository with
1697 a 200 year institutional control period.

1698 The following is a list of generic waste acceptance criteria for waste that should be
1699 accepted at any Australian near-surface repository. The waste:

- 1700 (a) is a solid;
- 1701 (b) has stable chemical and physical properties;
- 1702 (c) contains no free liquid;
- 1703 (d) is compatible with concrete and natural barriers;
- 1704 (e) does not contain compressed gases;
- 1705 (f) contains no hazardous material, such as PCBs, infectious waste, putrescible
1706 materials;
- 1707 (g) contains no organic liquids or chelating agents;
- 1708 (h) is structurally stable and have long term compressive strength;
- 1709 (i) will not generate gases;
- 1710 (j) does not contain flammable material;
- 1711 (k) contains less than 10 percent voidage; and
- 1712 (l) can be placed into a package that meets the *Code of Practice for the Safe*
1713 *Transport of Radioactive Material* (ARPANSA 2008).

1714 Once a waste repository is established there will be clear specifications for each of
1715 these waste acceptance criteria. The repository licence could define no free liquids as
1716 being less than 1 percent by volume, and that a given pressure will not release in the
1717 release of water. It might define a threshold of 100 part per million for defining when
1718 the presence of a hazardous material would not be accepted.

1719 Until a repository is established, the above list of criteria could be used as a basis for a
1720 proposal to undertake irreversible treatment of radioactive waste that is likely to be
1721 destined to a near-surface repository. Irreversible treatment of radioactive waste
1722 should only be undertaken where there are clear safety or security benefits.

1723 **Deep Borehole Facility**

1724 The following is a list of generic waste acceptance criteria for waste that should be
1725 accepted at an Australian borehole disposal facility: The waste:

- 1726 (a) is a solid;
1727 (b) has stable chemical and physical properties;
1728 (c) is small enough to fill in borehole;
1729 (d) contains no free liquid;
1730 (e) is structurally stable; and
1731 (f) can be placed into a package that meets the *Code of Practice for the Safe*
1732 *Transport of Radioactive Material* (ARPANSA 2008).

1733 Although boreholes can be drilled with diameters of a metre or more, deep large
1734 diameter boreholes are difficult and expensive. There is a trade off between total
1735 depth and borehole diameter. It is possible that the safety case for disposal of higher
1736 radioactivity sources in a borehole facility might put greater emphasis on increased
1737 depth rather than increased diameter.

1738 Standard drill rigs used for petroleum exploration can drill deep and could the
1739 drilling technology used if a borehole disposal facility is required to be deep.
1740 Boreholes produced by petroleum exploration drill rigs are likely to have an internal
1741 diameter of 150 mm or more (based on an 8.5 inch drill). To allow for overpacking,
1742 this suggests that to ensure it is suitable for any borehole facility, a stainless steel
1743 package for radium needles and tubes or higher activity sources should be 100 mm or
1744 less in diameter. Keeping packages 100 mm or less gives confidence that the waste
1745 will be able to be disposed of in any borehole disposal facility. Of course, if a borehole
1746 facility is established with a larger diameter borehole, then the waste acceptance
1747 criteria would be designed to accept larger diameter packages.

1748

1749 **Annex H**

1750

1751 **Health Effects of Ionizing Radiation and Standards for**
1752 **Control of Exposure**

1753 It is well known that high doses of ionizing radiation can cause harm, but there is
1754 continuing scientific uncertainty about effects at low doses. At levels of dose
1755 routinely encountered by members of the public and occupationally exposed persons,
1756 there is little or no epidemiological evidence of health effects. Radiation protection
1757 standards recognise that it is not possible to eliminate all radiation exposure, but they
1758 do provide for a system of control to avoid unnecessary exposure and to keep doses in
1759 the low dose range.

1760 Extreme doses of radiation to the whole body (around 10 sievert and above), received
1761 in a short period, cause so much damage to the body that vital systems cease to
1762 function and death may result within days or weeks. Very high doses (between about
1763 1 sievert and 10 sievert), received in a short period, kill large numbers of cells, which
1764 can impair the function of vital organs and systems. Acute health effects, such as
1765 nausea, vomiting, skin and deep tissue burns, and impairment of the body's ability to
1766 fight infection may result within hours, days or weeks. The extent of the damage
1767 increases with dose. However, 'deterministic' effects such as these are not observed
1768 at doses below certain thresholds. By limiting doses to levels below the thresholds,
1769 tissue reactions can be prevented entirely.

1770 Doses below the thresholds for tissue reactions may cause cellular damage, but this
1771 does not necessarily lead to harm to the individual: the effects are probabilistic or
1772 'stochastic' in nature. It is known that doses above about 100 millisievert, received in
1773 a short period, lead to an increased risk of developing cancer later in life. There is
1774 good epidemiological evidence – especially from studies of the survivors of the atomic
1775 bombings – that, for several types of cancer, the risk increases roughly linearly with
1776 dose, and that the risk factor averaged over all ages and cancer types is about 1 in 100
1777 for every 100 millisievert of dose (i.e. 1 in 10,000 per millisievert).

1778 At doses below about 100 millisievert, the evidence of harm is not clear-cut. While
1779 some studies indicate evidence of radiation-induced effects, epidemiological research
1780 has been unable to establish that there are effects of statistical significance at doses
1781 below a few tens of millisieverts. Nevertheless, given that no threshold for stochastic
1782 effects has been demonstrated, and in order to be cautious in establishing health
1783 standards, the proportionality between risk and dose observed at higher doses is
1784 presumed to continue through all lower levels of dose to zero. This is called the
1785 linear, no-threshold (LNT) hypothesis and it is made for radiation protection
1786 purposes only.

1787 There is evidence that a dose accumulated over a long period carries less risk than the
1788 same dose received over a short period. Except for accidents and medical exposures,
1789 doses are not normally received over short periods, so that it is appropriate in
1790 determining standards for the control of exposure to use a risk factor that takes this
1791 into account. While not well quantified, a reduction of the high-dose risk factor by a
1792 factor of two has been adopted internationally, so that for radiation protection
1793 purposes the risk of radiation-induced fatal cancer (the risk factor) is taken to be
1794 about 1 in 20,000 per millisievert of dose for the population as a whole.

1795 If the LNT hypothesis is correct, any dose carries some risk. Therefore, measures for
1796 control of exposure for stochastic effects seek to avoid all reasonably avoidable risk.

1797 This is called optimising protection. However, risk in this sense may often be
1798 assessed in terms of risk to a population, and may not ensure sufficient protection of
1799 the individual. Consequently, the optimisation approach is underpinned by applying
1800 dose limits that restrict the risk to individuals to an acceptable level. The
1801 fundamental regulatory philosophy is expressed in three principles, based on the
1802 recommendations of the International Commission on Radiological Protection
1803 (ICRP), which may be summarised as follows:

1804 *Justification:* human activities that cause exposure to radiation may be
1805 permitted only if they do more good than harm;

1806 *Optimisation of protection:* exposure to radiation from justified activities
1807 should be kept as low as reasonably achievable, social and economic factors
1808 being taken into account; and

1809 *Limitation of individual dose:* doses must not exceed the prescribed dose
1810 limits.

1811 Determining what is an acceptable risk for regulatory purposes is a complex value
1812 judgement. The ICRP reviewed a number of factors in developing its
1813 recommendations, which have in general been internationally endorsed, including by
1814 the World Health Organization, the International Labour Organization and the
1815 International Atomic Energy Agency. Australia's Radiation Health Committee, now
1816 established under the ARPANS Act[†], has recommended that the international
1817 standards be adopted in Australia. The recommended dose limits are summarised as
1818 follows:

1819 **Limit on effective dose***

	For occupational exposure	For members of the public
To limit individual risk	20 mSv per year, averaged over 5 years*	1 mSv in a year*

1824 *for details, see ARPANSA's *Recommendations for limiting exposure to ionizing radiation*
1825 (2002)

1826 In most situations, the requirements for limiting individual risk ensure that doses are
1827 below deterministic thresholds, but for cases where this does not apply, the
1828 recommended limits are as follows:

1829 **Annual limit on equivalent dose***

	For occupational exposure	For members of the public
To prevent tissue reactions		
in the lens of the eye	150 mSv	15 mSv
in the skin	500 mSv	50 mSv
in the hands and feet	500 mSv	—

1836 *for details, see ARPANSA's *Recommendations for limiting exposure to ionizing radiation*
1837 (2002)

[†] The *Australian Radiation Protection and Nuclear Safety Act (1998)*.

(Reference Pages)

1838 In the case of occupational exposure during pregnancy, the general principle is that
1839 the embryo or fetus should be afforded the same level of protection as is required for
1840 a member of the public. For medical workers, the ICRP recommends that there
1841 should be a reasonable assurance that fetal dose can be kept below 1 mGy* during the
1842 course of the pregnancy. This guidance may be generalised to cover all occupationally
1843 exposed pregnant workers by keeping the fetal dose below 1 mSv. A full explanation
1844 of radiation protection principles and of the recommended standards for Australia is
1845 given in ARPANSA/NOHSC Radiation Protection Series No. 1: *Recommendations for*
1846 *limiting exposure to ionizing radiation (1995)* and *National standard for limiting*
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* The gray (Gy) is a unit of radiation dose. For X-rays and gamma radiation, it is numerically equivalent to the sievert.

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