



DRAFT REPORT FOR FOR CONSULTATION

ICRP ref 4838-8963-9177  
July 21, 2011

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30

# Annals of the ICRP

ICRP PUBLICATION XXX

## Radiological Protection in Geological Disposal of Long-Lived Solid Radioactive Waste

Full members

W. Weiss (Chair), C.-M. Larsson, Chr. McKenney, J.-P. Minon, S. Mobbs, T.  
Schneider, H. Umeki

Corresponding members

W. Hilden, C. Pescatore, M. Vesterind

## Radiological protection in geological disposal of long-lived solid radioactive waste

ICRP Publication 1XX

**Abstract** –This report updates and consolidates previous recommendations of ICRP related to solid waste disposal (Publications 46, 77, 81). The recommendations given in this report apply specifically to geological disposal of long-lived solid radioactive waste. The report explains how the 2007 ICRP System of Radiological Protection described in ICRP Publication 103 can be applied in the context of the geological disposal of long-lived solid radioactive waste. The report is written as a self standing document.

The 2007 ICRP System of Radiological Protection maintains the Commission's three fundamental principles of radiological protection namely justification, optimisation, and the application of dose limits. The Recommendations evolve from the previous process-based protection approach using practices and interventions by moving to an approach based on the exposure situation. They maintain the Commission's current individual dose limits for effective dose and equivalent dose from all regulated sources in planned exposure situations. They re-enforce the principle of the optimisation of radiological protection. The Recommendations also include an approach for developing a framework to demonstrate radiological protection of the environment.

This report describes the different stages in the lifetime of a geological disposal facility and addresses the application of relevant radiological protection principles for each stage depending on the various exposure situations that can be encountered. In particular, the crucial factor that influences the application of the protection system over the different phases in the lifetime of a disposal facility is the level of oversight that is present. The level of oversight affects the capability to reduce or avoid exposures. Three main timeframes have to be considered for the purpose of radiological protection: time of direct oversight when the disposal facility is being implemented and active oversight is taking place; time of indirect oversight when the disposal facility is sealed and indirect oversight is being exercised to provide additional assurance on behalf of the society; time of no oversight when oversight is no longer exercised because memory is lost.

© 20XX ICRP. Published by Elsevier Ltd. All rights reserved.

Keywords: Geological disposal, Radioactive waste, Protecting future generations

### Table of Contents

75	
76	
77	
78	Abstract
79	Table of Contents
80	Preface
81	Executive Summary
82	
83	1. Introduction
84	
85	2. Scope of this report
86	
87	3. Basic values and goals underlying protection for a geological disposal of
88	radioactive waste
89	3.1 Values underlying the ICRP principles for protecting future generations
90	3.1.1 Basic values for the protection of future generations
91	3.1.2 Basic ICRP principles dealing with future generations
92	3.2 Geological Disposal: Objective and Implementation steps
93	3.2.1 Strategies for the management of long-lived solid radioactive
94	waste
95	3.2.2 Life phases of a disposal facility and safety analysis process
96	3.2.3 Relevant timeframes for protection
97	
98	4. Application of the ICRP system of protection during different timeframes in
99	the life of a geological disposal facility
100	4.1 The application of the basic principles “justification”, “limitation” and
101	“optimisation”
102	4.2 Dose and risk concepts
103	4.3 Exposure situations associated with geological disposal
104	4.3.1 Exposure Situations for Waste Emplacement Activities
105	4.3.2 Exposure Situations for the Emplaced Waste
106	4.3.3 Natural disrupting events
107	4.3.4 Inadvertent human intrusion
108	4.3.5 Summary of relevant exposure situation according oversight
109	4.4 Optimisation and Best Available Techniques
110	
111	5. „Endpoint considerations“
112	5.1 The Representative Person
113	5.2 Protection of the environment
114	
115	6. References
116	
117	Annex 1: The ICRP system of protection, focusing on aspects relevant to the
118	geological disposal of long-lived solid radioactive waste
119	Annex 2 ICRP use of „potential exposure“
120	Annex 3 Technical and management principles and requirements
121	
122	

## Preface

123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163

On February 12, 2010, the Main Commission of the International Commission on Radiological Protection (ICRP) approved the formation of a new Task Group, reporting to Committee 4, to develop a report which describes in plain language how the recommendations given in ICRP Publication 103 can be applied in the context of the geological disposal of long-lived solid radioactive waste. The report covers both the protection of humans (workers and the public) and the environment and discusses key issues like the transition from a planned to an existing exposure situation in case of a loss of control of the waste system as well as the applicability of dose calculated for the far future for decision aiding. The report updates ICRP Publication 81.

The report provides guidance on:

- the basic concepts and terms, eg. the radiation protection principles, the different types of situations (including human actions), dose and risk constraints;
- the nature and role of optimization (stepwise approach, short term vs. long term, best available technology);
- the use and application of dosimetric units and concepts (dose and risk constraints, potential exposures, collective dose, different time frames);
- the role of stakeholder involvement in different stages of planning and development.

The membership of the Task Group was as follows:

W. Weiss (Chair)	C.-M. Larsson	Chr. McKenney
J.-P. Minon	S. Mobbs	T. Schneider
H. Umeki		

The corresponding members were:

W. Hilden	C. Pescatore	M. Vesterind
-----------	--------------	--------------

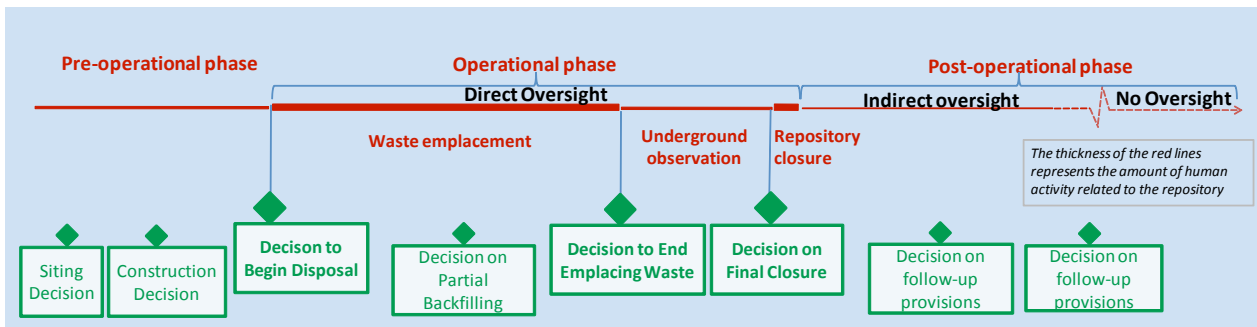
The Task Group wishes to thank those organizations and staff that made facilities and support available for its meetings. These include BfS, ARPANSA, NRC, NIRAS, HPA, CEPN, JAEA, EC, OECD/NEA, IAEA.

The report was approved by the Commission in XX in 2011.

164 **Executive summary**

165  
166  
167  
168  
169  
170  
171  
172  
173

(a) This report provides advice on the application of the Commission’s 2007 Recommendations (ICRP Publication 103) for the protection of humans and the environment against any harm that may result from the geological disposal of long-lived solid radioactive waste. It illustrates how the key protection concepts and principles of ICRP Publication 103 are to be interpreted and how they apply over the different timeframes over which a geological disposal facility for long-lived solid radioactive waste would have to provide radiological protection (see Figure).



174  
175

(b) The goal of a geological disposal facility is to isolate and contain the waste in order to protect humans and the environment for time scales that are comparable with geological time scales. At great distance from the surface, changes are particularly slow. With distance from the surface, and having chosen appropriate sites the potential for human intrusion will be limited. Radioactivity will decrease with time, and any release would be slowed down and diluted further by a properly chosen geological formation. Geological disposal is recognized by the international organisations as especially intended for high level radioactive waste or spent fuel where long term isolation and containment is required. Geological disposal may also be used for other long-lived wastes since a similar need for long term protection applies.

176

(c) The design of a geological disposal facility addresses a series of developments with different probabilities that may be defined by regulation. Besides these design-basis developments, the developer / implementer and the regulator may want to assess evolutions in non-design-basis conditions in order to judge the robustness of the system.

177

(d) These ICRP recommendations describe the radiological concepts and criteria that ought to be used by both the designer and/or operator of the facility and the regulator. For the assessment of the safety and radiological protection of a geological disposal facility for long-lived radioactive waste various dose and risk constraints are used. Optimisation deals with the main aim of a disposal system, i.e., the radiological protection of humans and the environment. Optimisation of protection is the central element of the step-wise construction and implementation of a geological disposal facility. It has to cover all elements of the system, including the societal component, in an integrated way. Important aspects of optimisation of protection must occur prior to waste emplacement, largely during the siting and design phase. The optimisation efforts can be informed by, and construction supplemented with, consideration of best available technique (BAT) as applied to all stages of disposal facility siting and

178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205

206 design. During the implementation phase, some further optimisation is possible but  
207 very little can be done to further optimise the performance of the engineered features  
208 after waste emplacement has occurred. In the long term optimisation of protection  
209 can only be achieved if oversight is maintained.  
210

211 (e) In the distant future the geological disposal facility might give rise to some  
212 releases to the accessible environment and the “safety case” has to demonstrate that  
213 such releases, should they occur, are compatible with regulation and radiological  
214 protection criteria. In application of the optimisation principle, the reference  
215 radiological impact criterion for the design of a waste disposal facility recommended  
216 by ICRP is an annual dose constraint for the population of 0.3 mSv in a year [ICRP  
217 103], without any weighting of doses in the far future. For less likely events resulting  
218 in potential exposures, the Commission continues to recommend a risk<sup>1</sup> constraint for  
219 the population of  $1 \cdot 10^{-5}$  per year. However, ICRP Publication 103 also warns that,  
220 given the long timeframes considered in waste disposal, the evolution of society,  
221 human habits and characteristics is such that effective dose loses its direct  
222 connection to health detriment after the time span of a few generations. At the same  
223 time, in the distant future, the geosphere and the engineered system and, even more,  
224 the biosphere will evolve in a less predictable way. The scientific basis for dose and  
225 risk assessments at very long times into the future then becomes questionable and  
226 the strict application of numerical criteria may be inappropriate. Hence, the annual  
227 dose constraint of 0.3 mSv in a year is to be used for the sake of comparison of  
228 options rather than as means of assessing health detriment.  
229

230 (f) In particular, a crucial factor that influences the application of the protection  
231 system over the different phases during the lifetime of a geological disposal facility, is  
232 the level of oversight that is present. The level of oversight directly affects the  
233 capability to reduce or avoid some exposures. Three main timeframes have to be  
234 considered: the time of direct oversight when the disposal facility is being  
235 implemented and active oversight is taking place (operational phase); the time of  
236 indirect oversight when the disposal facility is partly (backfilling and sealing of drifts)  
237 or fully sealed (post-closure period) where direct regulatory oversight might be  
238 supplemented or replaced by institutional oversight (e.g. restriction of land use) and  
239 the time of absence of oversight (post-closure period in distant future) in case  
240 memory is lost, although the primary objective is to keep memory of the site.  
241

242 (g) The exposures arising from the design basis evolution of the geological disposal  
243 facility are planned exposure situations as defined in ICRP Publication 103. They  
244 include potential exposures from events with low probability which have to be  
245 considered as part of the design basis. If severe disturbing events outside the design  
246 basis occur while there is still oversight (direct or indirect) of the disposal facility and  
247 which result in doses largely exceeding 0.3 mSv in a year, the ensuing situation will  
248 be considered as an emergency exposure situation followed by an existing exposure  
249 situation in case this emergency is resulting in a long lasting contamination of the  
250 environment. If a severe disturbing event occurs when there is no longer any  
251 oversight of the disposal facility, there is no certainty that a competent authority  
252 would be able to understand what is the source of the exposure and therefore, it is

---

<sup>1</sup> Risk is used in this document always to mean **radiological risk** as defined in ICRP Publication 103.

253 not possible to consider with certainty the implementation of relevant  
254 countermeasures to control the source. However, there is a need to evaluate the  
255 consequences within the scope of an existing exposure situation.  
256

257 (h) For the “design basis” evolution, the dosimetric criteria relevant to planned  
258 exposure situations will be considered for assessing the safety and robustness of the  
259 disposal facility. For a severe disturbing event, the reference level to be considered  
260 for emergency exposure situation would apply when relevant (i.e. reference level in  
261 the range of 20 to 100 mSv for the first year). It is also necessary to evaluate the  
262 possible consequences of the occurrence of such events on the basis of the  
263 dosimetric criteria relevant for existing exposure situation as defined by ICRP (i.e.  
264 reference level of a few mSv per year).  
265

266 (i) The safety case of a geological disposal facility, by including events that are not  
267 expected to occur with high certainty, includes automatically considerations on how  
268 to deal with potential exposures as defined by ICRP Publication 103 (section 6.1.3).  
269

270 (j) ICRP recommends that dose or risk estimates derived from these exposure  
271 assessments should not be regarded as direct measures of health effects beyond  
272 timescales of around several hundred years into the future. Rather, they represent  
273 indicators of the protection afforded by the geological disposal system.  
274

275 (k) The application of the three exposure situations and of dose limits, constraints  
276 and reference levels as defined in ICRP Publication 103 during these timeframes is  
277 indicated in Table 1.  
278



279

RADIOLOGICAL EXPOSURE SITUATIONS AS FUNCTION OF DISPOSAL FACILITY EVOLUTION AND PRESENCE AND TYPE OF OVERSIGHT			
Disposal facility Status	Type of Oversight		
	Direct Oversight	Indirect Oversight	No oversight
Design-basis <sup>1</sup> evolution	Planned Exposure Situation <sup>2</sup>	Planned Exposure Situation <sup>2</sup>	Planned Exposure Situation <sup>2,3</sup>
Non-design basis evolution involving significant exposures to people and the environment	Emergency Exposure Situation at the time of exposure, followed by an Existing Exposure Situation <sup>4</sup>	Emergency Exposure Situation at the time of exposure, followed by an Existing Exposure Situation <sup>4</sup>	Emergency and/or Existing Exposure Situation
Inadvertent Human Intrusion	not relevant	not relevant	Emergency and/or Existing Exposure Situation

280 <sup>1</sup> The design basis is the envelope of both expected and less likely (potential) events that are used in planning the  
 281 facility.

282 <sup>2</sup> At design: 20 mSv in a year dose limit to worker and dose constraint to be specified by operators; 1 mSv in a  
 283 year dose limit and 0.3 mSv in a year dose constraint for the public, in the case of less likely events within the  
 284 design basis a risk constraint of  $1 \cdot 10^{-5}$  per year for the public is suggested.

285 <sup>3</sup> No worker dose is foreseen during the period of no oversight

286 <sup>4</sup> For an emergency exposure situation a reference level between 20 and 100 mSv per year is recommended; for  
 287 an existing exposure situation a reference level should be selected in the lower part of the band between 1  
 288 and 20 mSv per year, eg., in the range of a few mSv per year.  
 289



## 290 1. Introduction

291  
292 (1) In the context of the Commission's recommendations, waste is any material for  
293 which no further use is foreseen. Waste, as generated, includes liquid and gaseous  
294 effluents as well as solid materials. Waste storage is the temporary retention of  
295 waste. Waste disposal is the permanent isolation and containment of waste in an  
296 appropriate facility. Waste management means the whole sequence of operations  
297 starting with the generation of waste and ending with disposal.

298  
299 (2) This report deals with geological disposal of long-lived solid radioactive waste  
300 which is intended to isolate and contain especially high level waste, spent fuel and  
301 intermediate level wastes containing radionuclides with long half lives. These are  
302 concentrated wastes which contain high specific activities; they need to be handled  
303 remotely, for hundreds or thousands of years. The report does not address near  
304 surface disposal facilities because they differ from geologic disposal facilities in two  
305 key aspects: the isolation and containment function and the waste for which they are  
306 intended.

307  
308 (3) Technical solutions for the permanent isolation of long-lived, solid radioactive  
309 waste at distances from the surface of hundreds of metres in geological formations  
310 are being developed and pursued in a number of countries. Geological disposal is  
311 currently recognized by international organisations in charge of radioactive waste  
312 management as especially suited for high level radioactive waste or spent fuel where  
313 long term containment is required. Geological disposal may also be used for other  
314 wastes containing long lived radionuclides since similar long-term protection  
315 requirements can be formulated. An example of geological disposal is the  
316 emplacement of waste in excavated tunnels or shafts, followed by backfilling and  
317 sealing of the entire facility.

318  
319 (4) The goal of a geological disposal facility is to achieve the isolation and  
320 containment of the waste and to protect humans and the environment for time scales  
321 that are comparable with geological changes. At great distance from the surface,  
322 such changes are particularly slow and, at the same time, radioactivity will decrease  
323 with time. Additionally, if a site is chosen in an area with no known natural resources,  
324 the potential for human intrusion will be limited. Finally, a properly chosen geological  
325 formation would assure stable chemical conditions for the waste. Further, it would  
326 attenuate and slow down any releases of radionuclides. In this context 'distance' can  
327 imply horizontal or vertical distance as, for example the case of a disposal facility  
328 sited deep within a mountain.

329  
330 (5) The safety strategy implemented for geological disposal is that to concentrate and  
331 retain the waste. No exposure is ever intended, although these may happen. The  
332 disposal facility is thus to be seen as a functional facility whose controls are in-built  
333 and whose safety, after facility closure, does not rely on the presence of man. The  
334 safety function to be fulfilled by a geological disposal facility independent of man is to  
335 isolate and contain the waste over as long a period of time as possible. This will allow  
336 radioactive decay to take place and attenuate and delay the eventual release of any  
337 contaminants to the accessible environment. Furthermore, it will reduce the risk of  
338 inadvertent human intrusion. In the situation of a human intrusion the health

339 consequences for the intruder might be high. But this is an inescapable consequence  
340 of the decision to concentrate waste in a disposal facility.

341  
342 (6) Geological disposal of long-lived solid radioactive waste poses a number of  
343 challenges related to radiological protection over extended periods of time, e.g. the  
344 nature and role of optimization of protection during the various phases of the  
345 development and implementation of the disposal facility and the applicability of dose  
346 and risk calculated for the far future for decision aiding. The report explains how the  
347 protection principles as laid out in ICRP Publication 103 can be applied under these  
348 circumstances. It also considers elements that can assist in demonstration of  
349 compliance with the protection principles and how the principles, in broad terms,  
350 relate to other protective goals that would be considered in an environmental impact  
351 assessment/statement.

352  
353 (7) Radiological protection is only one set of the protection concepts that will be used  
354 by safety analysts in documenting the protection capability of the disposal facility.  
355 Other concepts may relate to the protection of resources in a sustainable way such  
356 as for example groundwater as a drinking water resource. The chemical toxicity of  
357 the waste or the waste containment system in a disposal facility for radioactive waste  
358 may be a further issue of concern. Optimal protection would be achieved by the  
359 application of an integrated framework of protection concepts in which the level of  
360 protection of humans, the environment and the resources are comparable for  
361 radiotoxic and chemotoxic substances.

362  
363 (8) The Commission has previously published protection recommendations for the  
364 disposal of long-lived radioactive waste (ICRP Publications 46, 77, 81) consistent  
365 with its general recommendations for the application of its overall System of  
366 Radiological Protection (ICRP Publication 60). More recently, the Commission has  
367 published new general recommendations (ICRP Publication 103). This report  
368 summarizes and explains how these recommendations specifically apply to a  
369 geological disposal facility for long-lived solid radioactive waste.

370  
371 (9) This report is written as a stand-alone presentation of the Commission's  
372 Publication 103 system of radiological protection as it should be applied in the  
373 context of geological disposal of long-lived radioactive waste. It covers all issues  
374 related to radiological protection of humans and the environment against harm that  
375 may result from the geological disposal of long-lived solid radioactive waste. Where  
376 the Commission's recommendations are unchanged, or issues are addressed  
377 sufficiently in publications by other international organisations, references are given  
378 and no detailed discussion is provided.

379  
380 (10) In the case of geological disposal, the occupational exposure of workers and the  
381 exposure of the public are managed in accordance with the ICRP system of  
382 protection. The main protection issue dealt with in this report concerns exposures  
383 that may or may not occur in the far future. Any corresponding estimates of doses to  
384 individuals and populations will have growing associated uncertainties as a function  
385 of time due to incomplete knowledge of the future disposal system behaviour, of  
386 geological and biospheric conditions, and of human habits and characteristics.  
387 Furthermore, due to the long timescales, verification that protection is being achieved

388 cannot be expected in the same manner as for current discharges since knowledge  
389 of the disposal facility may eventually be lost and oversight may be absent. Neither  
390 can it be assumed that effective mitigation measures will necessarily be carried out,  
391 should they be required in the far future. Nevertheless, the Commission's system of  
392 protection can be applied to the disposal of long lived solid radioactive waste, with  
393 due interpretation.

394

## 395 **1.1 References**

396

397 ICRP (1985) Protection Principles for the Disposal of Solid Radioactive Waste. ICRP  
398 Publication 46, Annals of the ICRP 15 (4).

399 ICRP (1991) 1990 Recommendations of the International Commission on  
400 Radiological Protection. ICRP Publication 60, Annals of the ICRP 21 (1–3).

401 ICRP (1997) Radiological Protection Policy for the Disposal of Radioactive Waste.  
402 ICRP Publication 77, Annals of the ICRP 27 Supplement 1997.

403 ICRP (1998) protection recommendations as applied to the disposal of long-lived  
404 solid radioactive waste. ICRP Publication 81, Annals of the ICRP 28 (4).

405 ICRP (2007). The 2007 Recommendations of the International Commission on  
406 Radiological Protection. ICRP Publication 103, Annals of the ICRP 37 (2–4).

407

## 408 **2. Scope of this report**

409

410 (11) This report deals with the radiological protection of workers, members of the  
411 public and the environment, following the disposal of long-lived solid radioactive  
412 waste in geological disposal facilities. The recommendations given in this report  
413 apply to disposal facilities where there is still an opportunity for their implementation  
414 during the site selection, design, construction, and operational phases. They should  
415 also be taken into account in the justification of decisions involving practices  
416 generating waste.

417

418 (12) The report does not describe the disposal safety assessment in detail. It rather  
419 provides a description of how protection criteria can be used in the safety analysis,  
420 and establishes recommendations on protection issues related to the disposal of  
421 long-lived solid radioactive waste. Exposures are estimated in order to place  
422 adequate control on the source of exposure. The characteristics and habits of  
423 exposed individuals and populations are taken into account.

424

425 (13) The report does not address near surface facilities because they differ from  
426 geological facilities with respect to the isolation function and the waste for which they  
427 are intended. Near surface facilities principally rely on the engineering containment  
428 provided by the facility and on the presence of man. The long term stability of the  
429 surrounding soil or rock and its attenuation properties are of secondary importance.  
430 Also, they are by definition more easily accessible and hence a near surface facility  
431 can only provide short term isolation of the waste. Near surface facilities are suitable  
432 for low and intermediate level wastes containing predominantly shorter lived and less  
433 concentrated levels of radionuclides. The differences in the functions of near surface  
434 facilities and geological facilities, together with the different wastes they receive,  
435 result in the application of specific regulatory regimes: one for near surface disposal  
436 and one for geological disposal. Previous ICRP recommendations for the radiological

437 protection of workers, members of the public and the environment in the case of near  
438 surface disposal facilities or other disposal options are still valid.  
439  
440

441 **3. Basic values and goals underlying protection for a geological disposal of**  
442 **radioactive waste**

443  
444 **3.1 Values underlying the ICRP principles for protecting future generations**

445  
446 **3.1.1 Basic values for the protection of future generations**

447  
448 (14) The initial composition of radionuclides contained into long lived radioactive  
449 waste evolves over time, changing the nature of the hazard. At the same time, even  
450 though the activity decreases with time, the halflife of some radionuclides, and the  
451 rate of ingrowth of others, are such that some of these wastes may never be  
452 considered as not being a hazard.

453  
454 (15) Over the last decade, reflections on safety and societal issues associated with  
455 this long-term dimension clearly point out the complexity of the situation: on one hand  
456 it is not possible to envisage how the society will be organized in the far future while  
457 on the other hand the current generation has to take care of the possible future in  
458 order to design the waste management strategy. This is notably the core of the  
459 ethical reflections regarding the precautionary principle and sustainable  
460 development, in order to preserve the resources and the environment for the future  
461 generations.

462  
463 (16) The 1997 Joint Convention on the Safety of Spent Fuel Management and on the  
464 Safety of Radioactive Waste Management details the long-term aspects of the safety  
465 objectives for disposal by requiring to meet the principle that "...individuals, society  
466 and the environment are protected from harmful effects of ionising, now and in the  
467 future, in such a way that the needs and aspirations of the present generation are  
468 met without compromising the ability of future generations to meet their needs and  
469 aspirations" (IAEA 1997). In a broad sense this principle is consistent with one of the  
470 recommendations of ICRP Publication 77: "the Commission recommendations rely  
471 on the basic principle that individuals and populations in the future should be afforded  
472 at least the same level of protection as the current generation." These  
473 recommendations were further expanded and clarified in ICRP Publication 81  
474 (paragraphs 41 and 42).

475  
476 (17) In the same vein, the obligations of the present generation toward the future are  
477 complex, involving, for instance, not only issues of safety and protection but also of  
478 transfer of knowledge and resources. Due to the technical and scientific uncertainties  
479 and to the evolution of society in the long-term, it is generally acknowledged that the  
480 capacity of the present generation to guarantee delivery of its obligations diminishes  
481 with distance in time.

482  
483 **3.1.2 Basic ICRP principles dealing with future generations**

484  
485 (18) The main strength of ICRP consists in its unified protection system applicable to  
486 all types of exposure situations. In its 2007 Recommendations (ICRP Publication  
487 103), the ICRP protection system continues to rely on its three fundamental  
488 principles: justification, optimisation of protection and application of dose limits,  
489 applied according to the exposure situation considered.

490

491 (19) The optimisation principle is of primary importance and its role has been  
492 reinforced in the new ICRP Recommendations. For this purpose, ICRP recommends  
493 that, in assessing the level of protection for humans, “the likelihood of incurring  
494 exposures, the number of people exposed, and the magnitude of their individual  
495 doses should all be kept as low as reasonably achievable, taking into account  
496 economic and societal factors” (ICRP Publication 103, paragraph 203).

497

498 (20) For this assessment, two concepts are considered by ICRP: dose and risk.  
499 Associated with dose and risk, the concept of health detriment, as introduced by  
500 ICRP in its Publication 26, is also a key concept to consider for assessing the level of  
501 protection. The application of this concept aims at providing an estimate of the total  
502 harm to health to individuals and their descendants as a result of an exposure,  
503 assuming a linear-non-threshold dose-effect relationship. For exposures that may  
504 occur in the long-term, the relevance and meaning of dose and risk is of interest and  
505 their interpretation over the different time periods has to be clarified. It should be  
506 noted that the knowledge of the relationship between dose and effect may very well  
507 change in the future, as has already been demonstrated by past reassessments of  
508 nominal probability coefficients. Likewise, the ability to cure or mitigate induced  
509 health effects may change in the future. It is not possible to make any prediction of  
510 the direction of these changes. Thus, the efforts to avoid and/or reduce any effect on  
511 human health and on the environment in the far future have to be entirely guided by  
512 the current understanding of health and environmental effects.

513

514 (21) Notwithstanding the uncertainty described above, the ICRP dosimetric quantities  
515 and the health detriment can be used for long-term assessment. In fact, the  
516 assessment of the robustness of the protection system provided by solid waste  
517 disposal in the long-term does not need a precise knowledge of the evolution of the  
518 general health of the population in the far future. At the design stage, what is at stake  
519 is not to evaluate what would be the level of health effects in a group of population in  
520 the far future. The challenge is rather to estimate, in an optimisation process through  
521 a comparison (using dose and risk indicators) of alternative options, the levels of  
522 protection achieved by a given disposal facility system and to judge if the estimated  
523 protection level of the chosen strategy is acceptable in the light of the level of  
524 protection accepted today.

525

## 526 **3.2 Geological disposal: Objective and Implementation steps**

527

### 528 **3.2.1 Strategies for the management of long-lived solid radioactive waste**

529

530 (22) Because of the nature and longevity of hazards, the fundamental strategy  
531 adopted for the management of long-lived radioactive waste in order to achieve the  
532 safety objective is to concentrate and contain the wastes and to isolate them from the  
533 environment as long as possible. The goal of a geological disposal facility is to  
534 provide protection of humans and the environment from the hazards that the  
535 radioactive waste and the waste containment system would pose over time. The  
536 current generation has to take care of the possible future developments when  
537 designing the waste management strategy. These possible developments imply  
538 different timescales with different levels of presence of human institutions but also



539 uncertainty concerning the level of presence of humans themselves.

540  
 541 (23) It is internationally recognized that only materials that have been declared as  
 542 having no further use for society (waste) are disposed of, so that there is no intention  
 543 by the current generation to retrieve it, even if technical options to do that were  
 544 available. Disposal is not to be confused with a storage situation. Currently, the  
 545 reference option is to dispose of these wastes in engineered deposition facilities  
 546 located in suitable geological formations [IAEA 1997, OECD-NEA 2008].  
 547

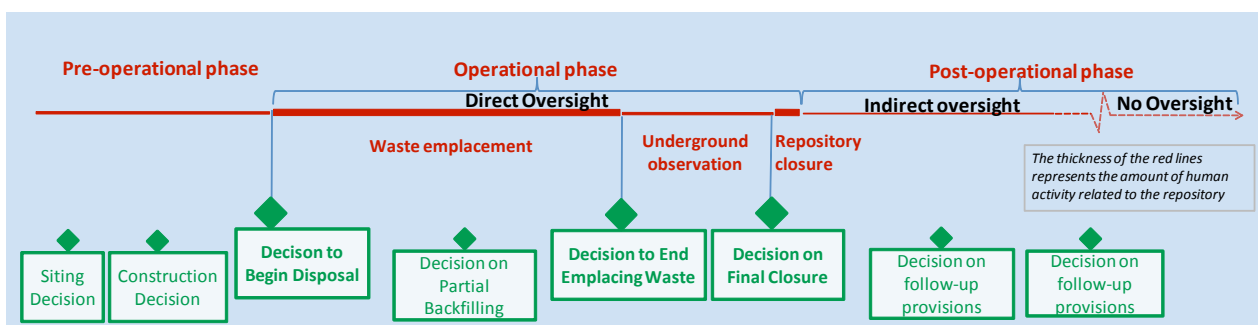
548 (24) A step-wise process, involving various stakeholders, is considered as a  
 549 responsible approach to planning for the disposal development and implementation,  
 550 including final closure. In that context the concepts of reversibility and retrievability  
 551 into the disposal facility programmes are also considered. Reversibility implies a  
 552 disposal programme that is implemented in stages, keeps options open at each  
 553 stage, and provides the capacity to manage the disposal facility with flexibility over  
 554 time. Retrievability is the possibility to reverse the step of waste emplacement during  
 555 the entire operational phase, e.g. before final closure of the disposal facility.  
 556 Retrievability does not imply the intention to retrieve nor is retrieval a contingency  
 557 plan for the disposal facility. The key is to consider any choices that could facilitate  
 558 retrieval if this was ever required but to continue to ensure that the integrity of the  
 559 facility is not jeopardised by these choices. The decision to actually carry out any  
 560 retrieval would be a separate decision taken in the future, according to the  
 561 radiological principles that apply to a new planned activity.  
 562

563 (25) The “concentrate and contain” strategy makes it possible, in principle, for the  
 564 waste to be re-accessed either voluntarily or involuntarily at some time in the future.  
 565 Therefore, disposal systems ought to be designed to reduce the possibility of  
 566 inadvertent or malevolent events. There are to some extent conflicting requirements  
 567 involved and a balance has to be found in each case, taking into consideration the  
 568 timescales, the nature of the waste, the nature of the host geological formation, and  
 569 the evolving desires of society.  
 570

571 **3.2.2 Life phases of a disposal facility and the safety analysis process**

572  
 573 (26) With respect to the presence of man for managing the facility, the development  
 574 of a geological disposal facility involves three main phases (Fig. 1) whose durations  
 575 vary amongst national programmes depending on the design and on each country’s  
 576 approach to decision making.  
 577

578 Fig. 1 Disposal facility life phases and relevant oversight periods



580



581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629

(27) The **pre-operational phase**: During this phase, the disposal facility is designed, the site is selected and characterized, the man-made materials are tested and the engineering demonstrated, safety cases for operational and post-operational phases are developed, the licenses for building and operation are applied for and received, and construction begins. A baseline of environmental conditions is also performed.

(28) The **operational phase**: During this phase, the emplacement of waste is performed, followed by a period of observation prior to the closure. At one time during this phase, some galleries will be filled and sealed and will have thus reached their final configuration, while others will still be excavated.

This phase will be under **direct oversight** of the safety authorities in cooperation with other relevant stakeholders and it may be divided into three relevant time periods:

- **The emplacement period**: A licence is granted that authorizes the transfer and emplacement of waste packages to underground in pre-excavated galleries, rooms, and/or boreholes. The environmental conditions are continuously monitored and compared to the baseline data. Research and development continues. The regulator performs regular inspections of the underground operations. The long-term safety case is regularly updated and reviewed by the regulator. In this phase, new underground galleries may be built and partial backfilling and/or sealing of galleries and disposal facility areas may also take place.
- **The observation period**: After all waste packages are emplaced it might be decided to monitor (parts of) the disposal facility and to keep some accessibility to at least part of the waste while additional performance confirmation takes place.
- **The closure period**: A license to close is granted and access from the surface to the underground facility is terminated. Backfilling and sealing are performed according to design. Surface facilities may be dismantled. The archives of all relevant information are to be provided for long-term preservation.

(29) The **post-operational phase**: during this phase the presence of man is no longer required to directly manage the facility. This phase is the longest one, and is divided into two relevant time periods:

- The **period of indirect oversight**: After closure, safety is assured totally through the intrinsic, built-in provisions of the design of the disposal facility. Nevertheless, it is expected to continue monitoring of the baseline environmental conditions including some remote monitoring. Archives on technical data and configuration of waste packages and the disposal facility will be kept, as well as markers to remind coming generations of its existence. The relevant international safeguards controls continue to apply. Inadvertent human intrusion in the disposal facility can be ruled out.
- The **period of no oversight**: Although termination of indirect oversight is not foreseen, it will still have to be considered in the design and planning stage as there is no guarantee that it will be maintained as well as the memory of the

630 site in the distant future. Eventually, loss of oversight and memory may take  
631 place, either progressively or following major unpredictable events such as  
632 war or loss of records. Therefore, inadvertent human intrusion in the disposal  
633 facility cannot be ruled out during this time period. The intrinsic hazard of the  
634 waste will decrease with time but it may continue to pose a significant hazard  
635 for a considerable time. The loss of oversight does not result in a change of  
636 the protection capability of the disposal facility.

637  
638 (30) As long as oversight is effective, it will be possible to evaluate the protection  
639 capability of the disposal facility based on regular updates of the safety case. The  
640 safety case provided by the developer of a disposal facility must address the  
641 operational and the post-operational phase and, specifically the distant future, when  
642 controls and interventions cannot be relied upon. The aim of the developed safety  
643 case is to provide convincing evidence of the intrinsic protective capability of the  
644 system. The safety case shows how the barriers in the disposal facility system work  
645 together and how they fulfil their desired functions over time. It documents the  
646 principles and strategies that were followed for developing the knowledge base. It  
647 recognises the residual uncertainties in both the long-term processes and potential  
648 future events that may affect the performance of the disposal facility and why these  
649 have been considered as not to reduce protection unduly. Interactions with the  
650 various stakeholders - e.g., the local public, outside experts brought in to conduct  
651 independent reviews - are acknowledged elements to enhance the quality of the  
652 decision-making process at the different phases of the disposal facility development  
653 and implementation.

### 654 3.2.3 Relevant timeframes for radiological protection

655 (31) As stated before, the scope of this ICRP report is the description of how  
656 protection criteria can be used in the safety assessment, and to establish  
657 recommendations on protection issues related to the disposal of long-lived solid  
658 radioactive waste. One of the crucial factors that influences the application of the  
659 protection system over the different phases in the lifetime of a disposal facility is the  
660 level of oversight that is present. The level of oversight will directly affect the  
661 capability to reduce or avoid some exposures. Three main timeframes have to be  
662 considered:

- 663 • **Time of direct oversight:** when the disposal facility is being implemented  
664 and active oversight is taking place. This timeframe coincides with the pre-  
665 operational and operational phases of the disposal facility;
- 666 • **Time of indirect oversight:** when the disposal facility is sealed and indirect  
667 oversight is being exercised to provide additional assurance on behalf of the  
668 society. This timeframe coincide with the post-operational phase of the  
669 disposal facility.
- 670 • **Time of no oversight:** when oversight is no longer exercised because  
671 memory is lost. This timeframe coincides with the post-closure period in the  
672 distant future.

673  
674 The transition between the different timeframes has also to be considered

675 (32). During the time of direct oversight both the operator and the regulator in  
676 interaction with the concerned stakeholders will be able to actively manage the  
677 protection of workers, the public and the environment through direct and indirect  
678 actions. The transition from this timeframe into the timeframe of indirect oversight is  
679 not abrupt. Thus parts of the disposal facility will be under direct oversight, and at the  
680 same time others will be under indirect oversight.

681 (33) During the time of indirect oversight, there might be some presence of  
682 people/staff/operator at the site. Knowledge is maintained, monitoring may continue  
683 to occur and some corrective actions could be made if needed. However, in most  
684 cases, options to address radiological protection will be indirect. As time progresses  
685 the degree of oversight may change, corresponding, for example, to less frequent  
686 inspections. The decisions to reduce the level of oversight would be based to some  
687 extent on the degree of confidence in the behavior of the facility, and other societal  
688 and economic factors. Decisions related to the organization and evolution of the  
689 oversight should be discussed with the stakeholders concerned.

690 (34) It is to be expected that regulators and society will maintain forms of oversight  
691 and memory as long as possible. However, there is no guarantee on there existence  
692 in the distant future. At this point the facility implicitly leaves the regulatory regime.

693 (35) No matter in which way oversight ceases to exist, the disposal facility is still a  
694 functioning facility and continues to be so. The potential to isolate and contain the  
695 radioactive waste is an inherent feature of the radioactive waste disposal facility that  
696 continues into the far future and responds to the considered evolution of the disposal  
697 facility under natural processes and events. The multi-barrier, multi-function system  
698 that is at the basis of the disposal facility design must have the potential to constrain  
699 releases of radionuclides from the radioactive waste disposal facility.

700 (36) Another type of passive control that may continue after the direct oversight  
701 ceases is provided by memory or records of the presence of a geological disposal  
702 facility or other measures decided by the authorities in interaction with the different  
703 stakeholders, however for a much shorter timescale. This reduces the probability of  
704 direct inadvertent intrusion by people into the facility and it may assist in the  
705 justification and planning for any advertent intrusion, if desired. At some point in the  
706 distant future, the memory of the presence of the disposal facility may be lost and  
707 there is no defense mechanism against direct inadvertent intrusion, apart from the  
708 fact that the waste is out of sight and stored at great distance from the part of the  
709 biosphere that people normally inhabit. The location of the geological disposal facility  
710 and its technical design will constitute the remaining built-in "control" against  
711 inadvertent intrusion.

712 (37) The cessation of direct oversight of the site will not occur before tens to  
713 hundreds of years after the start of operations. It is not possible to specify the criteria  
714 that will be used by the people making decisions at that time. The different decisions  
715 to be made related to the evolution of the oversight should be discussed with the  
716 stakeholders.

717 (38) As such, the assumption that cessation of indirect oversight will occur does not  
718 correspond to a regulatory decision to release radioactive materials from regulatory  
719 control.

720

721

722 **4. Application of the ICRP system of protection during different timeframes in**  
723 **the life of a geological disposal facility**

724  
725 (39) The major features of the 2007 ICRP Recommendations (ICRP Publication 103)  
726 relevant to this report are:

- 727 • Maintaining the Commission’s three fundamental principles of radiological  
728 protection, namely justification, optimisation, and the application of dose limits,  
729 and clarifying how they apply to sources delivering exposure and to individuals  
730 receiving exposure.
- 731 • Evolving from the previous process-based protection approach using practices  
732 and interventions, by moving to a situation-based approach applying the  
733 fundamental principles of justification and optimisation of protection to all  
734 controllable exposure situations, which the 2007 ICRP Recommendations  
735 characterise as planned, emergency, and existing exposure situations.
- 736 • Re-enforcing the principle of optimisation of protection, which should be  
737 applied in a similar way to all exposure situations, with restrictions on  
738 individual doses and risks, namely dose and risk constraints for planned  
739 exposure situations and reference levels for emergency and existing exposure  
740 situations.

741  
742 **4.1 The application of the principles “justification”, “limitation” and**  
743 **“optimisation”**

744  
745 (40) The definitions of the three basic principles and basic considerations for their  
746 application to waste disposal are described as follows.

- 747  
748 • The Principle of Justification: *“Any decision that alters the exposure situation*  
749 *should do more good than harm.”*

750 Waste management and disposal operations are an integral part of the  
751 practice generating the waste. It is wrong to regard them as a free standing  
752 practice that needs its own justification. The waste management and disposal  
753 operations should therefore be included in the assessment of the justification  
754 of the practice generating the waste (ICRP 77 §34). This assessment should  
755 include considerations of different options for waste management and disposal  
756 including the justification of these options. If the national waste disposal policy  
757 has changed and the practice is continuing, it may be necessary to reassess  
758 the justification of the practice. If the practice has ceased, the protection  
759 strategy, rather than the practice, has to be considered for justification.

- 760  
761 • The Principle of Optimisation of Protection: *“The likelihood of incurring*  
762 *exposure, the number of people exposed, and the magnitude of their*  
763 *individual doses should all be kept as low as reasonably achievable, taking*  
764 *into account economic and societal factors.”*

765 As clearly stated in ICRP Publication 103, optimisation is of primary  
766 importance and its role has been reinforced. This is also the key principle  
767 guiding the application of the ICRP system of protection in the disposal of  
768 long-lived solid radioactive waste, as discussed in this report (for details see  
769 section 4.4).

770

- 771 • The Principle of Application of Dose Limits: *“The total dose to any individual*  
772 *from regulated sources in planned exposure situations other than medical*  
773 *exposure of patients should not exceed the appropriate limits specified by the*  
774 *Commission.”*

775 The general statement of ICRP Publication 81 (paragraph 36) still applies:  
776 “Although the Commission continues to recommend dose limits, it recognises  
777 that ‘dose limits for public exposure are rarely limiting in practice’ (ICRP,  
778 Publication 77, 1997b, paragraph 36). Furthermore, it considers that ‘...the  
779 application of dose limits to waste disposal has intrinsic difficulties’ (ICRP,  
780 Publication 77, 1997b, paragraph 19) and that control of public exposure  
781 through a process of constrained optimisation will ‘obviate the direct use of the  
782 public exposure dose limits in the control of radioactive waste disposal’ (ICRP,  
783 Publication 77, 1997b, paragraph 48).”  
784

## 785 4.2 Dose and risk concepts

786  
787 (41) The main and primary use of the effective dose in radiological protection for both  
788 workers and the general public is (ICRP Publication 103, paragraph 153):

- 789 • The prospective dose assessment for planning and optimisation of protection.  
790 • The retrospective dose assessment for demonstrating compliance with dose  
791 limits, or for comparing with dose constraints or reference levels.  
792

793 In practical radiological protection applications, effective dose is used for the  
794 demonstration of compliance with protection standards.  
795

796 (42) A potential exposure is an exposure that is not expected to be delivered with  
797 certainty but that may result from an accident at a source or an event or sequence of  
798 events of a probabilistic nature, including equipment failures and operating errors.  
799 The risk associated with such an event is a function of the probability of an  
800 unintended event causing a dose, and the probability of detriment due to that dose.  
801 Risk constraints correspond to dose constraints but refer to potential exposures. For  
802 potential exposures of workers, the Commission continues to recommend a generic  
803 risk constraint of  $2 \cdot 10^{-4}$  per year which is similar to the probability of fatal cancer  
804 associated with an average occupational annual dose of 5 mSv (ICRP Publication  
805 76). For potential exposures of the public, the Commission continues to recommend  
806 a risk constraint of  $1 \cdot 10^{-5}$  per year.

## 807 4.3 Exposure situations associated with geological disposal

808  
809 (43) The ICRP system of protection described in its Publication 103 distinguishes  
810 three types of radiological situations: planned, existing and emergency situations  
811 (ICRP Publication 103, paragraph 176).

- 812 • **“Planned exposure situations** are everyday situations involving the  
813 operation of deliberately introduced sources including decommissioning,  
814 disposal of radioactive waste including the post-closure phase and  
815 rehabilitation of the previously occupied land. Planned exposure situations  
816 may give rise both to exposures that are reasonably anticipated to occur  
817 (normal exposures) and to higher exposures that are anticipated to occur with



818 a lower likelihood (potential exposures). These may arise following deviations  
819 from normal operating procedures, but are considered at the planning stage.”

- 820 • **“Emergency exposure situations** are situations that may occur during the  
821 operation of a planned situation, or from a malicious act, or from any other  
822 unexpected situation, and require urgent action in order to avoid or reduce  
823 undesirable consequences.”
- 824 • **“Existing exposure situations** are exposure situations that already exist  
825 when a decision on control has to be taken, including prolonged exposure  
826 situations after emergencies.”

827

#### 828 **4.3.1 Exposure situations for waste emplacement activities**

829

830 (44) In terms of the basic types of exposure situations, waste emplacement activities  
831 are subject to the same principles of dose limitations and the requirement to optimise  
832 below constraints as those in any nuclear facility. Both worker and public exposures  
833 are expected from the transportation, handling and disposal activities and thus, are  
834 planned exposures including potential exposures from deviations from the normal  
835 operations. The possibility also exists for incidents due to low probability/high  
836 consequence initiating events, which could lead to an emergency situation.  
837 Operations would be expected to be optimized consistent with the Commission’s  
838 Recommendations in ICRP Publication 103. The annual dose limits for worker of e.g.  
839 20 mSv in a year is applied with the obligation of optimising protection below dose  
840 constraints to be specified by operators. The recommended dose constraint for the  
841 public is 0.3 mSv in a year. At the end of the period of direct oversight worker  
842 exposures are to be considered in two limited areas of exposure: (1) worker  
843 exposure for any indirect monitoring of the facility and its surroundings during the  
844 period of indirect oversight, and (2) exposure due to residual radioactivity after  
845 decommissioning of the surface facilities.

#### 846 **4.3.2 Exposure situations for the emplaced waste**

847

848 (45) For the emplaced waste, a typical disposal facility safety assessment would  
849 suggest that significant releases are unlikely during the emplacement period and the  
850 period of time during which a competently sited, operated and sealed disposal facility  
851 is being actively observed and monitored. Therefore, any exposures would be  
852 categorised as part of the potential exposure subset of planned exposure. Given the  
853 potentially vast time periods involved in the period of no oversight, the possibility of  
854 an eventual release of some radioactive substances is inherent in the concept of  
855 geological disposal even if the system operates as intended (i.e., without deviations  
856 from procedures in operations, construction or accidents). These very long term  
857 potential releases of radioactive substances and subsequent exposures are assumed  
858 to result from a variety of scenarios. While they may be foreseen and perhaps  
859 assigned a probability they are still intrinsically uncertain. Evaluations of these  
860 exposures serve the purpose of comparing alternative facility design options and  
861 reaching a regulatory judgment regarding the capability of the system to isolate and  
862 contain the waste. Such evaluations are not considered to be predictions, nor are  
863 they intended to be used for the protection of specific individuals or populations.  
864 Such exposures may in fact be projected to occur at such distant times that  
865 traditional concepts such as dose and risk have to be used with caution.

866



867 (46) Any such releases would be expected to take place well beyond the operational  
868 period of the facility so that the immediate causes of any release would be beyond  
869 the control of the operator; this suggests that these are uncertain and hence treated  
870 as potential exposures. The timing and magnitude of such releases is not predictable  
871 except in the broadest sense. Even more, the presence of exposed populations at  
872 the point of release as well as their capability to implement protective and/or  
873 corrective actions in the far future cannot be assumed certain, should such releases  
874 occur.

875 (47) The process of evaluating the potential exposure from emplaced waste includes  
876 the understanding of the potential ways by which the radionuclides could be released  
877 from the engineered facility, including the transport through the geosphere to the  
878 biosphere and the resultant release into an appropriate environmental compartment  
879 that could give rise to exposures to humans, flora or fauna. Depending on the level of  
880 knowledge, probabilities may be estimated for these release scenarios. However, at  
881 the long timescales considered in geological disposal, evolution of the biosphere and,  
882 possibly, the geosphere and the engineered system will increase the uncertainty of  
883 these probabilities. Hence the scientific basis for dose and risk assessments at very  
884 long times into the future may become questionable and the results of such  
885 assessments would then need to be interpreted in a qualitative way.

886 (48) The expected evolution of a geological disposal facility in the distant future  
887 should not require active involvement to mitigate the consequences as this is counter  
888 to the principle of avoiding placing an undue burden on future generations.  
889 Therefore, the Commission continues to support its recommendations in ICRP  
890 Publication 103 that either a dose constraint of 0.3 mSv in a year or an annual risk  
891 constraint of  $1 \times 10^{-5}$  be used for potential exposures from the emplaced waste. As  
892 noted in ICRP Publication 103, it may be useful to disaggregate the probability and  
893 potential consequence to reach risk-informed decisions.

894 (49) In the distant future, in case oversight provisions are no longer operational and  
895 the memory of the presence of the disposal facility is lost, it is possible that people  
896 will 'rediscover' the disposal facility. This may be without compromising its integrity  
897 (eg. remote sensing), by observing very small discharges into the biosphere, or it  
898 may be by directly breaching the containment, albeit inadvertently, and causing  
899 contamination of the environment. Situations of this kind would be treated as an  
900 existing exposure situation and be handled as appropriate to the protection  
901 guidelines at the time. However, these guidelines are inherently unknowable and  
902 thus, while noted, are not relied on for protection decisions today.

### 903 **4.3.3 Natural disruptive events**

904 (50) The disposal facility and its surrounding environment could be impacted or  
905 altered by natural disruptive events, e.g., earthquakes, during the periods of indirect  
906 oversight or no oversight. Different scenarios can be envisaged in the future  
907 according to the current knowledge. For these events, it may be possible to estimate  
908 or bound the probability of occurrence, and the risk of potential consequences should  
909 be taken into account in reaching risk-informed waste management decisions.

910 (51) Natural disruptive events with very low probability compared to the design-basis  
911 may occur and may induce significant disturbances on the disposal system or the  
912 migration of the radioactive substances. Examples of these types of events include  
913 major landform change due to tectonic events, etc. Assessing their probabilities of  
914 occurrence may neither be relevant nor feasible. The Commission recommends that  
915 the regulatory authority develop a strategy for addressing such events with the  
916 involvement of relevant stakeholders. Possible approaches include establishing a  
917 probability value for which events with lesser probabilities are excluded from  
918 consideration in the risk-assessment process, optimizing site selection to minimize  
919 the probability of such events, or assessing specific events through stylized  
920 assessments.

921 (52) Previously the Commission considered all natural events, disruptive or not,  
922 within the same framework (Publication 81). Now, the Commission recommends  
923 separate consideration of natural disruptive events which are included in the design-  
924 basis evolution from those which are not. For the first ones, the Commission  
925 recommends application of the dose or risk constraints for planned exposure  
926 situation. For the severe natural disruptive events not taken into account in the  
927 design-basis evolution, the Commission now recommends application of the  
928 reference levels for emergency or existing exposure situations, depending on the  
929 severity of the consequences. If the events were to occur, while there is still (direct or  
930 indirect) oversight of the disposal facility, the authorities should be in a position to  
931 implement adequate protection measures to deal with this situation as emergency or  
932 existing exposure situation. If such a disruptive event occurs when oversight of the  
933 disposal system has disappeared, there is no certainty about the possibility that an  
934 organisation could be aware of the disturbance and therefore, it is not possible to  
935 consider with certainty the implementation of protective measures. If the authorities  
936 eventually became aware of the disturbance they would treat the situation as an  
937 emergency exposure situation or an existing exposure situation depending on the  
938 severity of the disturbance.

939 (53) For emergency exposure situations, the Commission recommends selection of a  
940 reference level in the range of 20 mSv to 100 mSv for the first year and development  
941 of protection strategies to reduce exposures to as low as reasonably achievable  
942 below the reference level taking into account economic and societal factors  
943 (Publication 109).

944 (54) According to Publication 103, long-lasting exposures resulting from natural  
945 disruptive events (with or without an emergency phase) should be referred to as an  
946 existing exposure situation and the recommended reference levels to be selected for  
947 optimizing protection strategies ranges between 1 to 20 mSv per year. In agreement  
948 with the Commission's recommendations in Publication 111, a reference level should  
949 be selected in the lower part of the band, e.g., in the range of a few mSv per year.

#### 950 **4.3.4 Inadvertent human intrusion**

951 (55) In general, waste is disposed in a geological disposal facility if it needs to be  
952 isolated from possible human intrusion (IAEA, 2009). It is necessary to distinguish  
953 between deliberate and inadvertent human intrusion into the facility. The first one is  
954 not discussed further in this report as it is considered out of the scope of

955 responsibility of the current generation to protect a deliberate intruder, i.e. a person  
956 who is aware of the nature of the facility. The design and siting of the facility will have  
957 to include features to reduce the possibility of inadvertent human intrusion.

958 (56) A release resulting from inadvertent human intrusion, such as drilling into the  
959 facility, could migrate through the geosphere and biosphere resulting in exposures  
960 that are indirectly related or incidental to the intrusion event. It is also possible that  
961 inadvertent human intrusion could bring waste material to the surface and hence lead  
962 to direct exposure of the intruder and nearby populations. This introduces the  
963 possibility of elevated exposures and significant doses which is an inescapable  
964 consequence of the decision to isolate and contain waste rather than diluting or  
965 dispersing it.

966 (57) Protection from exposures associated with human intrusion is best  
967 accomplished by efforts to reduce the assumed possibility of such events. These  
968 may include siting a disposal facility at great distance from the surface, avoiding  
969 assumed valuable resources, incorporating robust design features which make  
970 intrusion more difficult, or employing direct oversight (such as restricting access or  
971 monitoring for releases) and indirect passive oversight (such as archived record and  
972 site markers). While the actual probability of human intrusion at a specific site is  
973 largely unknowable as it is based on future human actions, it is assumed that the  
974 probability of intrusion during the direct and indirect oversight periods is effectively  
975 zero.

976 (58) For longer time periods, in case oversight has disappeared, the occurrence of  
977 human intrusion cannot be totally ruled out. Therefore, the consequences of one or  
978 more plausible stylised intrusion scenarios should be considered by the decision-  
979 maker to evaluate the resilience of the disposal facility to potential inadvertent  
980 intrusion. Any estimates of the magnitude of intrusion risks are by necessity  
981 dependent on assumptions that are made about future human behavior. Since no  
982 scientific basis exists for predicting the nature or probability of future human actions,  
983 the Commission continues to consider not appropriate to include the probabilities of  
984 such events in a quantitative performance assessment that is to be compared with  
985 dose or risk constraints (Publication 81). If recognized at the time an intrusion occurs,  
986 it would be treated as an emergency exposure situation or an existing exposure  
987 situation depending on the severity of the related disturbance.

988 (59) The Commission wishes to emphasise that the dose criteria specified in  
989 Publication 81 for human intrusion only apply to near surface disposal. In case of  
990 geological disposal, intrusion means that many of the barriers which were considered  
991 in the optimization of protection for the disposal facility have been by-passed. Since a  
992 future society may be unaware of the radiation risk associated with such events, any  
993 protective actions required should be considered during the development of the  
994 disposal system. Therefore the dose or risk constraints recommended by the  
995 Commission for the application of the optimization of protection in geological disposal  
996 do not apply to inadvertent human intrusion.

#### 997 **4.3.5 Summary of relevant exposure situation according oversight**

998  
999 (60) The application of the three exposure situations and of dose limits, dose



1000 constraints and reference levels as defined in ICRP Publication 103 during these  
1001 timeframes is indicated in Table 1.  
1002  
1003

1004

RADIOLOGICAL EXPOSURE SITUATIONS AS FUNCTION OF DISPOSAL FACILITY EVOLUTION AND PRESENCE AND TYPE OF OVERSIGHT			
Disposal facility Status	Type of Oversight		
	Direct Oversight	Indirect Oversight	No oversight
Design-basis <sup>1</sup> evolution	Planned Exposure Situation <sup>2</sup>	Planned Exposure Situation <sup>2</sup>	Planned Exposure Situation <sup>2,3</sup>
Non-design basis evolution involving significant exposures to people and the environment	Emergency Exposure Situation at the time of exposure, followed by an Existing Exposure Situation <sup>4</sup>	Emergency Exposure Situation at the time of exposure, followed by an Existing Exposure Situation <sup>4</sup>	Emergency and/or Existing Exposure Situation
Inadvertent Human Intrusion	not relevant	not relevant	Emergency and/or Existing Exposure Situation

1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014

<sup>1</sup> The design basis is the envelope of both expected and less likely (potential) events that are used in planning the facility.  
<sup>2</sup> At design: 20 mSv/a dose limit to worker and dose constraint to be specified by operators; 1 mSv/a dose limit and 0.3 mSv/a dose constraint for the public; in the case of less likely events within the design basis a risk constraint of  $1 \cdot 10^{-5}$  per year for the public is suggested.  
<sup>3</sup> No worker dose is foreseen during the period of no oversight  
<sup>4</sup> For an emergency exposure situation a reference level between 20 and 100 mSv per year is recommended; for an existing exposure situation a reference level should be selected in the lower part of the band between 1 and 20 mSv per year, eg., in the range of a few mSv per year.

1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032

#### 4.4 Optimisation and Best Available Techniques

(61) The principle of optimisation is defined by the Commission (ICRP Publications 101 and 103) as the source-related process to keep the likelihood of incurring exposures (where these are not certain to be received), the number of people exposed, and the magnitude of individual doses as low as reasonably achievable, taking economic and societal factors into account. The general recommendations for the optimisation process are described in ICRP Publication 101, part 2.

(62) The ICRP principle of optimisation of radiological protection when applied to the development and implementation of a geological disposal facility has to be understood in the broadest sense of an iterative, systematic and transparent evaluation of options for enhancing the protective capabilities of the system and for reducing impacts (radiological and others).

(63) Optimisation of protection has to deal with the main aim of disposal systems, i.e. to protect humans and the environment, now and in the future, by isolating the waste from man, the environment and the biosphere and by containing the radioactive and

1033 other toxic substances in the waste to the largest extent possible. Optimisation of  
1034 protection has to deal with the protection of workers and the public during the time of  
1035 operation, as well as with the protection of future generations including possible  
1036 periods with no oversight, and safety has to be ensured by a passively functioning  
1037 disposal system.

1038  
1039 (64) The stepwise decisional process for geological disposal facility development and  
1040 implementation constitutes the framework for the optimisation process. As a central  
1041 component, optimisation has to cover all elements of the disposal system in an  
1042 integrative approach, i.e. site (incl. host formation), facility design, the application of  
1043 Best Available Techniques (BAT), waste package design, waste characteristics as  
1044 well as all relevant time periods.

1045  
1046 (65) Optimisation of protection is a multi-facet endeavour, involving the disposal  
1047 facility developer, safety and environmental protection authorities, local communities  
1048 and other stakeholders and multiple decisions have to be taken. Therefore, it is not  
1049 possible to define a priori the path for a sound optimisation process for a geological  
1050 disposal facility, or the acceptance or success criteria for the end result of an  
1051 optimisation process.

1052  
1053 (66) Socio-economical factors (including e.g. policy decisions and societal  
1054 acceptance issues) can constraint the optimisation process to various extents, e.g.  
1055 by limiting the available options (e.g. siting) and/or by defining additional conditions  
1056 (e.g. retrievability). It is important that these constraints are identified in a manner  
1057 transparent to all involved stakeholders and that their safety implications are  
1058 generally and broadly understood. These factors must not force the optimisation  
1059 process to accept options that are questionable from a protection point of view.

1060  
1061 (67) Although optimisation is a continuous effort, milestones will have to be defined in  
1062 the stepwise process, where all involved stakeholders can judge the result of the  
1063 optimisation process and indicate ways to improve various elements of the system.

1064  
1065 (68) The process of optimisation will be considerably different for the pre-operational,  
1066 operational and post-operational phases. During the operational phase, the general  
1067 recommendations for any large nuclear facility apply. Experience gained during the  
1068 operational phase can be factored into immediate or near term improvements,  
1069 reducing the exposure to both workers and the public from the emplacement work.

1070  
1071 (69) Nearly all aspects of optimisation for the post-operational phase must occur prior  
1072 to waste emplacement, largely in the siting and design phase, with the plans to close  
1073 the facility being part of the design phase. Some further optimisation of the protection  
1074 that will be provided during the post-operational phase is still possible during the  
1075 operational phase, for example as new materials or techniques may become  
1076 available. Experience gained during the closure of parts of the facility, e.g. sealing of  
1077 disposal rooms, can lead to improvements of the plans of the disposal facility closure.

1078  
1079 (70) During the post-operational phase, there is no active operation of the disposal  
1080 facility. The waste is emplaced and the protection of humans and the environment is  
1081 mainly based on the passive isolation and containment capabilities of the disposal



1082 system. Hence decisions on optimisation in the post-operational phase can only  
1083 relate to the time and method of oversight of the closed disposal system. During this  
1084 phase optimisation of protection can best be achieved by maintaining oversight.  
1085

1086 (71) Geological disposal facilities are sited, designed and implemented to provide for  
1087 robust long-time isolation and containment, resulting in potential impacts on humans  
1088 and the environment only in the very far future. Consequently, as explained earlier,  
1089 the assessment of post-closure radiological impacts through the estimation of  
1090 effective dose or risk to a reference person, given the increasing uncertainties with  
1091 time and the cautious assumptions to be made, can only provide an indication or  
1092 illustration of the robustness of the system, rather than predictions of future  
1093 radiological consequences. As previously discussed, there comes a time in the  
1094 distant future beyond which any such calculated dose or risk values must be  
1095 considered for the sake of comparison of options rather than as absolute values.  
1096

1097 (72) The elements guiding or directing the optimisation process should be those that  
1098 directly or indirectly determine the quality of the components of the facility as built,  
1099 operated and closed, where quality refers to the capacity of the components to fulfil  
1100 the safety functions of isolation and containment in a robust manner. The  
1101 assessment and judgment of the quality of system components essentially includes  
1102 elements of BAT as well as the concepts of good practice and sound engineering  
1103 and managerial principles. These elements complement and support radiological  
1104 optimisation when potential impacts in the far future have to be dealt with.  
1105

1106 (73) The judgment of the quality of the system design developed or implemented has  
1107 to be made, and critically reviewed when needed, in a well-structured and  
1108 transparent process, with the involvement of all relevant stakeholders. At the heart of  
1109 this process is the interaction, transparent for all other stakeholders, between the  
1110 developer and the safety authorities.  
1111

1112 (74) When dealing with safety in the more distant future, optimisation can be  
1113 complemented and supported by applying the concept of BAT on the various levels  
1114 of the disposal system, through:  
1115

- 1116 - the methodologies for identifying and selecting (a) host rock(s), zones and  
1117 sites, and the methodological and scientific program of host rock and site  
1118 characterization in order to assess its containment and isolation capacities  
1119 now and in the distant future;
- 1120 - the development of the system design, including the choices of materials and  
1121 technologies, and the way they will contribute, individually and together, to the  
1122 main aim of isolation and containment, taking due account of the  
1123 characteristics of the host rock;
- 1124 - the integration of waste, site and design characteristics within one disposal  
1125 system and the iterative assessment of the isolation and containment  
1126 capacities of the system as a whole;
- 1127 - the use of sound managerial and engineering methods and practices during  
1128 system construction, operation and closure, within an integrated management  
1129 system.  
1130



1131 (75) Optimisation on the basis of radiological criteria (effective dose and risk) is an  
1132 important part of the optimisation of the design and implementation process of the  
1133 disposal facility at specific “windows” and for specific aspects of the disposal facility,  
1134 e.g. when operational safety is assessed during the design development steps and  
1135 during preparation and implementation of operational procedures and activities.  
1136

1137 (76) The way the various elements of a disposal system can be optimized in an  
1138 integrative manner during system development varies to a large extent. First of all  
1139 stepwise optimisation decisions have to be taken mostly in a chronological order: e.g.  
1140 the decisions on the choice of a host rock and on one or a limited number of sites are  
1141 often prior to decisions on a detailed design. For the selection of a host rock and a  
1142 site, a balance has to be struck between technical criteria related to the safety of a  
1143 disposal system (long-term stability, barrier for radionuclide migration, absence or  
1144 presence of natural resources in the vicinity, ...) and the requirement of local or  
1145 supra-local societal acceptance. Favourable host rocks and sites can in a first step  
1146 be identified on the basis of broadly defined “required qualities”, taking due account  
1147 of the isolation and containment function(s) of the natural barriers and the natural  
1148 environment in the disposal system.  
1149

1150 (77) If several suitable host rocks or sites can be identified and evaluated the  
1151 decision in favour of one specific host rock or site will always be a multi-factor  
1152 decision, based on both qualitative and quantitative judgments. Radiological criteria  
1153 (e.g. calculated effective dose) are often of limited value for this multi-factor decision,  
1154 due to (1) the increasing uncertainties for longer assessment timescales, and (2) the  
1155 observation that often calculated radiological impacts are so low that they do not  
1156 constitute a discriminating factor for the choice of a host rock or site.  
1157

1158 (78) The assessment of the robustness of the disposal facility can contribute to  
1159 system optimisation, because it provides insight, quantitative or qualitative, in the  
1160 performance of the disposal facility and its components, in the relative contributions  
1161 of the various components to the overall system. So, the value of such an  
1162 assessment for the optimisation process is mainly through the insights it provides on  
1163 the relative contributions of the various components to the overall system objective of  
1164 isolation and containment, and how these contributions can be affected by disturbing  
1165 events and processes or by remaining uncertainties. The indicative nature of  
1166 calculated effective dose and risk in the very far future reduces their usefulness for  
1167 the optimisation process.  
1168

## 1169 **5. „Endpoint considerations“**

### 1170 **5.1 The Representative Person**

1171 (79) As general guidance, the Commission considers that its recommendations on  
1172 the estimation of exposures in Publication 101, part 1, apply. The Commission  
1173 therefore continues to recommend that for planned exposure situations exposures  
1174 should in general be assessed on the basis of the annual dose to the representative  
1175 person.  
1176  
1177

1178 (80) During the operational phase, management of exposures to workers and the  
1179

1180 public would be the same as for any other large nuclear facility. During the post-  
1181 operational phase, due to the long time-scales under consideration, the habits and  
1182 characteristics of the representative person, as well as those of the environment in  
1183 which it is located, can only be based on a number of assumptions. In that case, any  
1184 such representative person has to be hypothetical and stylized. The habits and  
1185 characteristics assumed for the individual in a distant future should be chosen on the  
1186 basis of reasonably conservative and plausible assumptions, considering site or  
1187 region specific information as well as biological and physiological determinants of  
1188 human life. Moreover, in many cases, different scenarios, each associated with  
1189 different representative persons, may be considered for the long term and have  
1190 different probabilities of occurrence, although establishing discreet probabilities may  
1191 be problematic. Thus, the scenario leading to the highest dose may not be linked to  
1192 the highest risk. It is therefore important for the decision-maker to have a clear  
1193 presentation of the different scenarios and their associated probabilities of  
1194 occurrence or at least with an appreciation of their corresponding probabilities.

1195  
1196 (81) As stated in ICRP Publication 101, part 1, for the purpose of protection of the  
1197 public, the representative person corresponds to an individual receiving a dose that is  
1198 representative of the more highly exposed individuals in the population. Therefore, it  
1199 should be assumed that the hypothetical representative person is located at the time  
1200 and place of the maximum concentration of radionuclides in the biosphere. This is an  
1201 assumption since the environment may have evolved such that humans are no  
1202 longer inhabiting these areas in the far future.

1203  
1204 (82) A representative person cannot be defined independently of the assumed  
1205 biosphere. Major changes may occur in the biosphere in the long-term due to the  
1206 action of natural forces in a similar manner to those occurring in the past. Human  
1207 actions may also affect the biosphere, but one can only speculate about human  
1208 behaviour in the long-term. In the definition of the scenarios, consideration of  
1209 biosphere changes should be limited to those due to natural forces. A representative  
1210 person and biosphere should be defined using either a site specific approach based  
1211 on site or region specific information or a stylized approach based on more general  
1212 habits and conditions; the use of stylized approaches will become more important for  
1213 longer time-scales.

1214  
1215 (83) In the long term, if radionuclides are present in the environment, exposures of  
1216 the representative person are expected to occur during a whole lifetime. The  
1217 Commission recommends in its Publication 101, part 1, to use three age categories  
1218 for estimating annual dose to the representative person, for comparison with annual  
1219 dose or risk criteria. (Note that the annual dose from the intake of a radionuclide  
1220 already includes a component relating to the fact that the radionuclide will deliver a  
1221 dose in successive years, the length of time being determined by the biological half  
1222 life of the radionuclide in the body). These categories are 0-5 years (infant), 6-15  
1223 years (child), and 16-70 years (adult). Decisions can also be made by considering  
1224 doses or risks on a lifetime exposure instead on a per annum scale. For the  
1225 comparison of doses to individuals of current and future generations, however, it may  
1226 be necessary to calculate doses for different age groups for future exposures from  
1227 the radioactive waste site or vice versa to calculate doses for a representative person  
1228 of the current generation on the basis of lifetime exposure.

1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272

## 5.2 Protection of the environment

(84) Illustration that the environment is protected against harmful effects of releases from facilities is an increasing requirement in national legislation and in relation to many human activities including the management of long-lived waste. ICRP has responded to this need as well as to a number of other requirements of ethical nature (as laid out in its Publication 91) by directly and specifically addressing environmental protection in ICRP Publication 103 and by offering a methodology to address this issue, as outlined in ICRP Publication 108.

(85) The ICRP approach considers the health of the environment (not the presence of contamination or other factors that may affect the environment as a resource), with the aim of “preventing or reducing the frequency of deleterious effects on fauna and flora to a level where they would have a negligible impact on the maintenance of biological diversity, the conservation of species, or the health status of natural habitats, communities and ecosystems” (ICRP Publication 103 para 30). The full evaluation of environmental impact would normally be assessed through the Environmental Impact Assessment process and in the Environmental Impact Statement, where effects will be considered within a broader context including such factors as inter alia, visual impact, chemotoxic impact, noise, land use and amenities.

(86) The default target for protection and protective actions could be the set of Reference Animals and Plants that have been described by ICRP and for which the relevant data sets have been derived (Publication 108). The use of Reference Animals and Plants offers on one hand a challenge for waste management which is at least similar to the challenges of demonstrating compliance with dose/risk standards; but, on the other hand, also offers an additional line of argument and reasoning in building a safety case, using endpoints that are different from, but complementary to, protection of human health. Consideration of environmental protection, where appropriate, would thus broaden the basis for risk-informed decision making and addressed issues that may have differing levels of importance for different stakeholders.

(87) Over the long time frames that are considered in waste disposal, the biosphere is likely to change, and even change substantially. Such changes entail biosphere evolution with time that is either natural, or enhanced or perturbed through human action. Contributing factors may be, e.g., climate change including glaciations cycles, and land uplift or depression. Understanding different biospheres today and assessing impacts in such biospheres based on an approach involving Reference Animals and Plants, may guide our understanding of future biosphere changes also for the purpose of environmental protection.

**6. References**

- 1273  
1274  
1275 IAEA, 1997. Joint Convention on the Safety of Spent Fuel Management and on the  
1276 Safety of Radioactive Waste Management. INFCIRC/546, IAEA, 24 December 1997.  
1277  
1278 IAEA, 2009. Classification of Radioactive Waste. IAEA Safety Standard Series No.  
1279 GSG-1, IAEA, November 2009.  
1280  
1281 ICRP, 1977. Recommendations of the International Commission on Radiological  
1282 Protection. ICRP Publication 26. Ann. ICRP 1 (3).  
1283  
1284 ICRP, 1985. Principles for the disposal of solid radioactive waste. ICRP Publication  
1285 46. Ann. ICRP 15 (4).  
1286  
1287 ICRP, 1991. 1990 Recommendations of the International Commission on  
1288 Radiological Protection. ICRP Publication 60. Ann. ICRP 21 (1–3).  
1289  
1290 ICRP, 1993. Protection from potential exposure: a conceptual framework. ICRP  
1291 Publication 64. Ann. ICRP 23 (1).  
1292  
1293 ICRP, 1997a. Protection from potential exposures: application to selected sources.  
1294 ICRP Publication 76. Ann. ICRP 27 (2).  
1295  
1296 ICRP, 1997b. Radiological protection policy for the disposal of radioactive waste.  
1297 ICRP Publication 77. Ann. ICRP 27 (Suppl).  
1298  
1299 ICRP, 1998. Protection recommendations as applied to the disposal of long-lived  
1300 solid radioactive waste. ICRP Publication 81. Ann. ICRP 28 (4).  
1301  
1302 ICRP, 1999. Protection of the public in situations of prolonged exposure. ICRP  
1303 Publication 82. Ann. ICRP 29 (1–2).  
1304  
1305 ICRP, 2003. A framework for assessing the impact of ionising on non-human  
1306 species. ICRP Publication 91. Ann. ICRP 33 (3).  
1307  
1308 ICRP, 2006. Assessing dose of the representative person for the purpose of  
1309 protection of the public and The optimisation of radiological protection: Broadening  
1310 the process. ICRP Publication 101. Ann. ICRP 36 (3).  
1311  
1312 ICRP, 2007a. The 2007 Recommendations of the International Commission on  
1313 Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2–4).  
1314  
1315 ICRP, 2007b. Scope of radiological protection control measures. ICRP Publication  
1316 104. Ann. ICRP 37 (4).  
1317  
1318 ICRP, 2008. Environmental Protection: the Concept and Use of Reference Animals  
1319 and Plants. ICRP Publication 108. Ann. ICRP 38 (4-6).  
1320  
1321 ICRP, 2009. Application of the Commission's recommendations for the protection of

- 1322 people in emergency exposure situations. ICRP Publication 109. Ann. ICRP 39 (1).  
1323  
1324 ICRP, 2010. Application of the Commission's Recommendations to the Protection of  
1325 People Living in Long-term Contaminated Areas after a Nuclear Accident or a  
1326 Emergency. ICRP Publication 111. Ann. ICRP 39 (3).  
1327  
1328 OECD-NEA, 2007. Regulating the Long-term Safety of Geological Disposal -  
1329 Towards a Common Understanding of the Main Objectives and Bases of Safety  
1330 Criteria – OECD-NEA, Dec. 2007.  
1331  
1332 OECD-NEA, 2008. Moving Forward with Geological Disposal of Radioactive Waste –  
1333 A Collective Statement by the NEA Radioactive Waste Management Committee –  
1334 OECD/NEA, 2008.  
1335  
1336 OECD-NEA, 2010. Main Findings in the International Workshop “Towards  
1337 Transparent, Proportionate and Deliverable Regulation for Geological Disposal” -  
1338 Tokyo, Japan, 20-22 January 2009 – OECD-NEA, March 2010.  
1339  
1340 WHO, 2008. Guidelines for Drinking-water Quality. Third Edition, WHO, Geneva,  
1341 2008.  
1342

1343 **Annex 1: The ICRP system of protection, focusing on aspects relevant to the**  
1344 **geological disposal of long-lived solid radioactive waste**  
1345

1346 The purpose of this annex is to summarize the key recommendations of ICRP  
1347 relevant to waste disposal.  
1348

1349 In its Publication 103, the ICRP Recommendations evolve from the previous process-  
1350 based protection approach using practices and interventions by moving to an  
1351 approach based on the exposure situation. They recognise planned, emergency, and  
1352 existing exposure situations, and apply the fundamental principles of justification and  
1353 optimisation of protection to all of these situations. They maintain the Commission's  
1354 current individual dose limits for effective dose and equivalent dose from all regulated  
1355 sources in planned exposure situations. They reinforce the principle of optimisation of  
1356 protection, which should be applicable in a similar way to all exposure situations,  
1357 subject to the following restrictions on individual doses and risks; dose and risk  
1358 constraints for planned exposure situations, and reference levels for emergency and  
1359 existing exposure situations. The Recommendations also include an approach for  
1360 developing a framework to demonstrate radiological protection of the environment.  
1361

1362 **I. Principles of Protection**  
1363

1364 The three fundamental principles of protection are  
1365

- 1366 • **Justification:** Any decision that alters the exposure situation should  
1367 do more good than harm. This means that, by introducing a new source, by  
1368 reducing existing exposure, or by reducing the risk of potential exposure, one  
1369 should achieve sufficient individual or societal benefit to offset the detriment it  
1370 causes.  
1371

1372 Waste management and disposal operations are an integral part of the  
1373 practice generating the waste. It is wrong to regard them as a free standing  
1374 practice that needs its own justification. The waste management and disposal  
1375 operations should therefore be included in the assessment of the justification  
1376 of the practice generating the waste (ICRP 77 §34). This assessment should  
1377 include considerations of different options for waste management and disposal  
1378 including the justification of these options. If the national waste disposal policy  
1379 has changed and the practice is continuing, it may be necessary to reassess  
1380 the justification of the practice. If the practice has ceased, the protection  
1381 strategy, rather than the practice, has to be considered for justification.  
1382

- 1383 • **Optimisation of protection:** the likelihood of incurring exposures, the  
1384 number of people exposed, and the magnitude of their individual doses should  
1385 all be kept as low as reasonably achievable, taking into account economic and  
1386 societal factors. This means that the level of protection should be the best  
1387 under the prevailing circumstances, maximising the margin of benefit over  
1388 harm. In order to avoid severely inequitable outcomes of this optimisation  
1389 procedure, there should be restrictions on the doses or risks to individuals  
1390 from a particular source.

- 1391 • **Application of dose limits:** The total dose to any individual from



1392 regulated sources in planned exposure situations other than medical exposure  
1393 of patients should not exceed the appropriate limits recommended by the  
1394 Commission. Regulatory dose limits are determined by the regulatory  
1395 authority, taking account of international recommendations, and apply to  
1396 workers and to members of the public in planned exposure situations.  
1397

### 1398 **The role of optimisation**

1399

1400 When optimising protection strategies, it is necessary to consider all aspects and  
1401 protective measures to reduce residual dose, questioning whether ‘the best has been  
1402 done in the prevailing circumstances, and if all that is reasonable has been done to  
1403 reduce doses’ (ICRP Publication 103, Para. 217). This approach focuses efforts on  
1404 optimising protection in order that individual exposures, from all pathways, resulting  
1405 from the operation of a waste disposal facility (i.e. residual doses) are judged to be  
1406 acceptable in the context of the circumstances being planned for and the expected  
1407 resources required/allocated for protection. This approach implies the simultaneous  
1408 optimisation of all protective measures that are included in the protection strategy,  
1409 implemented if necessary in a stepwise fashion to address prevailing circumstances  
1410 appropriately.  
1411

1412 All aspects of optimisation cannot be codified; rather, there should be a commitment  
1413 by all parties to the optimisation process. Where optimisation becomes a matter for  
1414 the regulatory authority, the focus should *not* be on specific outcomes for a particular  
1415 situation, but rather on processes, procedures, and judgements. An open dialogue  
1416 should be established between the authority and the operating management, and the  
1417 success of the optimisation process will depend strongly on the quality of this  
1418 dialogue.  
1419

1420 Societal values usually influence the final decision on the level of radiological  
1421 protection. Therefore, while this report should be seen as providing decision-aiding  
1422 recommendations mainly based on scientific considerations on radiological  
1423 protection, the Commission’s advice will be expected to serve as an input to a final  
1424 (usually wider) decision-making process, which may include other societal concerns  
1425 and ethical aspects, as well as considerations of transparency (ICRP Publication  
1426 101). This decision-making process may often include the participation of relevant  
1427 stakeholders rather than radiological protection specialists alone.  
1428

### 1429 **II. Types of exposures and of exposure situations**

1430

1431 The Commission distinguishes between three categories of exposure: occupational,  
1432 public, and medical exposures of patients.  
1433

1434 The Commission intends its Recommendations to be applied to all sources and to  
1435 individuals exposed to in the following three types of exposure situations which  
1436 address all conceivable circumstances (ICRP Publication 103, para.176).

- 1437 • **Planned exposure situations** are situations involving the deliberate  
1438 introduction and operation of sources; including decommissioning, disposal  
1439 of radioactive waste and rehabilitation of the previously occupied land.  
1440 Planned exposure situations may give rise both to exposures that are



1441 anticipated to occur (normal exposures) and to exposures that are not  
1442 anticipated to occur (potential exposures).

- 1443 • **Emergency exposure situations** are situations that may occur during the  
1444 operation of a planned situation, or from a malicious act, or from any other  
1445 unexpected situation, and require urgent action in order to avoid or reduce  
1446 undesirable consequences.
- 1447 • **Existing exposure situations** are exposure situations that already exist  
1448 when a decision on control has to be taken, including prolonged exposure  
1449 situations after emergencies.

1450  
1451 It follows that what the Commission has previously called ‘practices’ could be the  
1452 origin of planned, emergency, and existing exposure situations. The principles of  
1453 protection for planned situations also apply to occupational exposure in connection  
1454 with existing and emergency exposure situations.

### 1455 1456 **III. Dose concepts (effective dose, collective dose)**

1457  
1458 The main and primary uses of **effective dose** in radiological protection for both  
1459 occupational workers and the general public are (ICRP Publication 103, para. 153):

- 1460 • prospective dose assessment for planning and optimisation of protection; and
- 1461 • retrospective dose assessment for demonstrating compliance with dose limits,  
1462 or for comparing with dose constraints or reference levels.

1463 In practical radiological protection applications, effective dose is used for managing  
1464 the risks of stochastic effects in workers and the public.

1465  
1466 The overall exposure, which is projected to occur as a result of the emergency  
1467 exposure situation, should no protective actions be employed, is called the *projected*  
1468 *dose*. The dose that would result when a protection strategy is implemented is called  
1469 the *residual dose*. In addition, each protective measure will avert a certain amount of  
1470 exposure. This is referred to as *averted dose*.

1471  
1472 ICRP Publication 103, para. 159: For the purpose of optimisation of radiological  
1473 protection, predominantly in the context of occupational exposure, the Commission  
1474 has introduced **collective dose** quantities (ICRP Publication 26). These quantities  
1475 take account of the exposure of all individuals in a group over a given time period or  
1476 during a given operation executed by this group in designated areas. Collective  
1477 effective dose is not intended as a tool for epidemiological studies, and it is  
1478 inappropriate to use it in risk projections.

### 1479 1480 **IV. Dose limits, constraints and reference levels**

1481  
1482 (B 174) In practice, limits, constraints, reference levels, and action levels are defined  
1483 in terms of dose quantities in order to restrict the risks from exposure for both  
1484 occupational workers and the public. Since neither quantity can be directly  
1485 measured, they are assessed using other measurable quantities, models and  
1486 computations. Depending on the situation considered (occupational or public  
1487 exposure), different procedures are applied.

1488  
1489 **Dose limit**

1490 The value of the effective dose or the equivalent dose to individuals from planned  
1491 exposure situations that shall not be exceeded. Numerical values are given in Tab. 8  
1492 (ICRP Publication 103).

1493

#### 1494 **Dose constraint**

1495 A prospective and source-related restriction on the individual dose from a source,  
1496 which provides a basic level of protection for the most highly exposed individuals  
1497 from a source, and serves as an upper bound on the dose in optimisation of  
1498 protection for that source. For occupational exposures, the dose constraint is a value  
1499 of individual dose used to limit the range of options considered in the process of  
1500 optimisation. For public exposure, the dose constraint is an upper bound on the  
1501 annual doses that members of the public should receive from the planned operation  
1502 of any controlled source. Numerical values are given in Tab. 8 (ICRP Publication  
1503 103).

1504

#### 1505 **Reference level**

1506 In emergency or existing exposure situations, the reference level represents the level  
1507 of dose or risk, above which it is judged to be inappropriate to plan to allow  
1508 exposures to occur, and below which optimisation of protection should be  
1509 implemented. The chosen value for a reference level will depend upon the prevailing  
1510 circumstances of the exposure under consideration. Numerical values are given in  
1511 Tab. 8 (ICRP Publication 103).

1512

#### 1513 **Derived consideration reference level**

1514 For the purpose of environmental protection, ICRP has in Publication 108 identified  
1515 Derived Consideration Reference Levels (DCRLs). These are ‘bands’ of  
1516 environmental dose (expressed as absorbed dose) rates, spanning one order of  
1517 magnitude, for the different Reference Animals and Plants, that “can be considered a  
1518 band of dose rates within which there is likely to be some chance of deleterious  
1519 effects occurring to individuals of that type of Reference Animal or Plant...that, when  
1520 considered with other relevant information, can be used as a point of reference to  
1521 optimise the level of effort expended on environmental protection (Publication 108,  
1522 para. 195).

1523

1524 **Potential exposure** is an exposure that is not expected to be delivered with certainty  
1525 but that may result from an accident at a source or an event or sequence of events of  
1526 a probabilistic nature, including equipment failures and operating errors.

1527

#### 1528 **Risk constraint**

1529 A prospective and source-related restriction on the individual risk (in the sense of  
1530 probability of detriment due to a potential exposure) from a source, which provides a  
1531 basic level of protection for the individuals most at risk from a source and serves as  
1532 an upper bound on the individual risk in optimisation of protection for that source.  
1533 This risk is a function of the probability of an unintended event causing a dose, and  
1534 the probability of detriment due to that dose. Risk constraints correspond to dose  
1535 constraints but refer to potential exposures.

1536

1537 ICRP Publication 103, para. 268: Risk constraints, like dose constraints, are source-  
1538 related and in principle should equate to a similar health risk to that implied by the

1539 corresponding dose constraints for the same source. However, there can be large  
1540 uncertainties in estimations of the probability of an unsafe situation and the resulting  
1541 dose. Thus, it will often be sufficient to use a generic value for a risk constraint. In the  
1542 case of workers, this could be based on generalisations about normal occupational  
1543 exposures, rather than on a more specific study of the particular operation. For  
1544 potential exposures of **workers**, the Commission continues to recommend a generic  
1545 risk constraint of **2 10<sup>-4</sup> per year** which is similar to the probability of fatal cancer  
1546 associated with an average occupational annual dose of 5 mSv (ICRP, Publication  
1547 76). For potential exposures of the **public**, the Commission continues to recommend  
1548 a risk constraint of **1 10<sup>-5</sup> per year**.

1549

## 1550 **V. Protection of the environment.**

1551

1552 The Commission acknowledges that, in contrast to human radiological protection, the  
1553 objectives of environmental protection are both complex and difficult to articulate.  
1554 The Commission does however subscribe to the global needs and efforts required to  
1555 maintain biological diversity, to ensure the conservation of species, and to protect the  
1556 health and status of natural habitats, communities, and ecosystems. It also  
1557 recognises that these objectives may be met in different ways, that ionising may be  
1558 only a minor consideration – depending on the environmental exposure situation –  
1559 and that a sense of proportion is necessary in trying to achieve them (ICRP  
1560 Publication 103, para. 361).

1561

1562 The Commission therefore believes that the development of a clearer framework is  
1563 required in order to assess the relationships between exposure and dose, and  
1564 between dose and effect, and the consequences of such effects, for non-human  
1565 species, on a common scientific basis. This issue was first discussed in ICRP  
1566 Publication 91, and it was concluded that it was necessary to draw upon the lessons  
1567 learned from the development of the systematic framework for the protection of  
1568 human beings. This framework is based on an enormous range of knowledge that  
1569 the Commission attempts to convert into pragmatic advice that will be of value in  
1570 managing different exposure situations, bearing in mind the wide range of errors,  
1571 uncertainties, and knowledge gaps of the various databases (ICRP Publication 103,  
1572 para. 364).

1573

1574 The Commission does not therefore propose to set any form of ‘dose limits’ with  
1575 respect to environmental protection. However, by setting out data for some  
1576 Reference Animals and Plants, in a transparently derived way, and upon which  
1577 further action may be considered, the Commission offers practical advice as laid out  
1578 in Publication 108. The Commission will continue to develop this framework to  
1579 gather and interpret data in order to provide more comprehensive advice in the  
1580 future, particularly with regard to those aspects or features of different environments  
1581 that are likely to be of concern under different exposure situations (ICRP Publication  
1582 103, para. 370)

1583

## 1584 **VI. Stakeholder involvement**

1585

1586 Since the mid 90s, the involvement of stakeholders in decision making related to  
1587 protection issues has been recognised as a key process notably for favouring the

1588 understanding of the protection measures, improving the protection, adapting the  
1589 measures to the local context and ensuring the sustainability of the protection. ICRP  
1590 Publication 82 (1999) is the first ICRP Publication mentioning explicitly stakeholder  
1591 involvement: “Many situations of prolonged exposure are integrated into the human  
1592 habitat and the Commission anticipates that the decision-making process will include  
1593 the participation of relevant stakeholders, rather than radiological protection  
1594 specialists alone.” (para. 4).

1595  
1596 Furthermore, in ICRP Publication 91 (2003) stakeholder involvement is introduced as  
1597 part of the “principles” for protecting the environment: “The principle of informed  
1598 consent, which emphasises the need for communication and public involvement,  
1599 starting at the planning stage and well before decisions are taken from which there is  
1600 no return. Such transparency of decision making should enable analysis and  
1601 understanding of all stakeholder’s arguments... » (Current environmental  
1602 management principles, para. 47).

1603  
1604 In ICRP Publication 101 Part 1 (2006), dealing with Assessing Dose of the  
1605 Representative Person for the Purpose of Protection of the Public, there is a first  
1606 elicitation of the advantages of engaging stakeholders: “In the case of defining  
1607 characteristics of the representative persons, stakeholder involvement can play an  
1608 important role... In particular, stakeholders can be helpful in determining the  
1609 reasonableness, sustainability, and homogeneity of habit data. Collaboration with  
1610 stakeholders can significantly improve the quality, understanding and acceptability of  
1611 characteristics of the representative person, and also strengthen support for the  
1612 process and the results.” (Value of stakeholder input in characterising the  
1613 representative person, § 102).

1614  
1615 It is then reinforced in ICRP Publication 101 Part 2 (2006) as well as in ICRP  
1616 Publication 103 (2008) for the Optimisation of Radiological Protection: “The  
1617 involvement of stakeholders is a proven means to achieve incorporation of values  
1618 into the decision-making process, improvement of the substantive quality of  
1619 decisions, resolution of conflicts among competing interests, building of shared  
1620 understanding with both workers and the public, and building trust in institutions.  
1621 Furthermore, involving all concerned parties reinforces the safety culture and  
1622 introduce the necessary flexibility in the management of the radiological risk that is  
1623 needed to achieve more effective and sustainable decisions.” (The optimisation  
1624 process, ICRP Publication 101 Part 2, para. 39).

1625  
1626 More recently, stakeholder engagement processes were considered as key  
1627 components of the development of strategies in case of preparedness of emergency  
1628 situations and management of existing situations. (ICRP Publication 109 related to  
1629 the Application of the Commission’s Recommendations for the Protection of People  
1630 in Emergency Exposure Situations and ICRP Publication 111 related to the  
1631 Application of the Commission’s Recommendations to the Protection of People Living  
1632 in Long Term Contaminated Areas After a Nuclear Accident or a Radiological  
1633 Emergency).

1634  
1635 These considerations fully apply to radioactive waste management. The Commission  
1636 recognises that the nature and extent of stakeholder involvement may vary between

1637 countries, but suggests that engagement with stakeholders is an important  
1638 component to the justification and optimisation of protection strategies in waste  
1639 disposal projects. During planning, it is essential that the plan is discussed, to the  
1640 extent practicable, with relevant stakeholders, including other authorities and the  
1641 public. Otherwise, it will be difficult to implement the plan effectively during operation.  
1642 The overall protection strategy and its constituent individual protective measures  
1643 should have been worked through with all those potentially exposed or affected.

1644  
1645 In addition, because of the long time scale at stake, it is also necessary to consider  
1646 the role of stakeholders to deal with intergenerational transmission of knowledge and  
1647 memory of installations and protection strategies.  
1648



1649 **Annex 2 ICRP use of “potential exposure“**

1650

1651 ICRP has frequently used the term „potential exposure“ in its publications:

1652 *“.....The 1955 Conference on the Peaceful Uses of Atomic Energy had aroused*  
1653 *great interest in the development of atomic power plants throughout the world. In*  
1654 *time this would greatly increase the number of persons occupationally exposed*  
1655 *and would also bring about actual or **potential exposure** of other persons and*  
1656 *the population as a whole.” (ICRP Publications 1, 3, 4).*

1657

1658 Further uses of the term „potential exposure“ can be found in ICRP  
1659 recommendations related to various fields of radiological protection (Publ. 10, 36, 37,  
1660 40, 42, 43, 54, 57).

1661

1662 The first comprehensive discussion of the nature and application of the term  
1663 „potential exposure“ is given in ICRP Publ. 60 and 64 (Protection from potential  
1664 exposure):

1665 *“(2) exposure which might result from the introduction of a practice is also divided*  
1666 *into two broad categories: normal exposure and **potential exposure**. Normal*  
1667 *exposure is that exposure which can reasonably be expected to occur, i.e., the*  
1668 *exposure is predicted to occur with a probability of one or near one, independent*  
1669 *of the time when the exposure occurs. It includes both exposure from operations*  
1670 *conducted as planned as well as unintended high probability, low consequence*  
1671 *events. These events are nearly certain to occur during operations but result in*  
1672 *doses that are within prescribed limits. **Potential exposure** is exposure that,*  
1673 *while not certain to occur, can be anticipated as a result of introducing or*  
1674 *modifying a practice and to which a probability of occurrence can be assigned.*  
1675 *Such exposure involves consideration of risk which falls outside the general*  
1676 *boundaries considered for normal exposure. The occurrence of potential events*  
1677 *and the chances that such events will result in a dose to an individual or group of*  
1678 *individuals, when combined with the probability of effects from the expected*  
1679 *resulting dose, can be presented as an a priori probability of harm. The initial*  
1680 *consideration of potential exposures, therefore, should form part of the system of*  
1681 *protection applied to practices, but it should be recognised that the exposures, if*  
1682 *they occur, may lead to intervention (ICRP, 1991).”*

1683 *(4) Potential exposure situations may arise from the introduction of most, if not all,*  
1684 *practices and involve a large variety of potential consequences. .... There are*  
1685 *also potential exposure situations, such as those associated with radioactive*  
1686 *waste disposal, which can arise in the far distant future where consequences*  
1687 *become much more difficult to predict. Although safety for this wide spectrum of*  
1688 *situations should be governed by coherent and consistent principles, the level of*  
1689 *effort required to implement the principles and the formulation of acceptance*  
1690 *criteria will differ substantially depending on the complexity of the practice,*  
1691 *sophistication of the engineering safety systems and the possible consequences.*

1692 *(5) In practical application, a system of protection against potential exposure must*  
1693 *apply fundamental safety principles developed for complex technical systems.....*  
1694 *The report is intended to show how the fundamental safety principles can be*  
1695 *applied to all potential exposure situations..... Although the methods of*  
1696 *application of those principles may be less complex for a less complex source of ,*  
1697 *a conscientious application of the safety principles to the design and operation of*



1698 sources appears appropriate to reduce the risk of accidental exposure in many  
 1699 industrial and medical practices.  
 1700 (11) In order to maintain a strict coherence in the treatment of actual and potential  
 1701 exposures, it is necessary to extend the concept of detriment to include the  
 1702 probability of occurrence of the situation giving rise to the detriment.... emphasis  
 1703 has to be placed on one part of detriment - the probability of an attributable death.  
 1704 However, nominal probability coefficients for stochastic effects that include non-  
 1705 fatal cancer and severe hereditary effects can be used in considering detriment to  
 1706 individuals from potential exposure. It must also be recognised that the  
 1707 uncertainties in estimating the probability of occurrence will usually be much  
 1708 greater than the uncertainties in estimating the probability of the consequences,  
 1709 should the dose occur.  
 1710 (33) The system of radiological protection recommended by the Commission for  
 1711 proposed and continuing practices is based on the following general principles.  
 1712 (b) In relation to any particular source within a practice, the magnitude of  
 1713 individual doses, the number of people exposed and the likelihood of incurring  
 1714 exposures where these are not certain to be received should all be kept as low as  
 1715 reasonably achievable, economic and social factors being taken into account.  
 1716 This procedure should be constrained by restrictions on the doses to individuals  
 1717 (dose constraints), **or the risks to individuals in the case of potential**  
 1718 **exposures (risk constraints)**, so as to limit the inequity likely to result from the  
 1719 inherent economic and social judgments. (The optimisation of protection)  
 1720 (61) Limits are used in safety to control the risk to individuals from all stipulated  
 1721 sources of exposure. However, in order to establish requirements to constrain  
 1722 exposure to individuals from a particular source, the Commission has  
 1723 recommended the use of constraints in the process of optimisation, which are  
 1724 source related and should be established in a manner such that the sum of the  
 1725 risks from all relevant sources does not exceed the individual limit. **For the**  
 1726 **treatment of potential exposure, the Commission recommends that limits of**  
 1727 **risk be of the same order of magnitude as the health risk implied by the**  
 1728 **dose limits for normal exposures. However, the dose limits themselves are**  
 1729 **not applicable to potential exposure situations.**  
 1730

Table 1. Range of probabilities in a year from which constraint may be selected

Sequence of events leading to doses treated as part of normal exposures	$10^{-1}$ to $10^{-2}$
Sequence of events leading to stochastic effects only but above dose limits	$10^{-2}$ to $10^{-5}$
Sequence of events leading to doses where some radiation effects are deterministic	$10^{-5}$ to $10^{-6}$
Sequence of events leading to doses where death is likely to result	$< 10^{-6}$

1731  
 1732  
 1733 The guidance provided in Publication 64 has been used and further developed in  
 1734 ICRP Publications 73, 77, 81, 82, 92, 94 and 101.  
 1735

1736 **Publication 103** confirms the basic principles by the following statements:  
 1737 *Para. 176: Planned exposure situations are situations involving the deliberate*  
 1738 *introduction and operation of sources. Planned exposure situations may give rise*

1739 both to exposures that are anticipated to occur (normal exposures) and to  
1740 exposures that are not anticipated to occur (**potential exposures**).

1741 Para. 205: The Commission recommends that, when activities involving an  
1742 increased or decreased level of exposure, **or a risk of potential exposure**, are  
1743 being considered, the expected change in detriment should be explicitly included  
1744 in the decision-making process.

1745 Para 214: Optimisation is always aimed at achieving the best level of protection  
1746 under the prevailing circumstances through an ongoing, iterative process that  
1747 involves: evaluation of the exposure situation, **including any potential**  
1748 **exposures**...

1749 Para 229: In Table 4 the different types of dose restrictions used in the  
1750 Commission's system of protection (limits, constraints, reference levels) are  
1751 shown in relation to type of exposure situation and category of exposure. In  
1752 planned exposure situations, there are also **risk constraints in order to take**  
1753 **account of potential exposures**.

1754 Para 254: All categories of exposure can occur in planned exposure situations,  
1755 i.e., occupational exposure, public exposure, and medical exposure of patients.....  
1756 The design and development of planned situations should have proper regard **for**  
1757 **potential exposures** that may result from deviations from normal operating  
1758 conditions. Due attention should be paid to the assessment of **potential**  
1759 **exposures** and to the related issue of the safety and security of sources.  
1760 Chapter 6.1.3 provides further details.

1761 Para 265 states: "Events in which the potential exposures could occur far in the  
1762 future, and the doses be delivered over long time periods, e.g., in the case of  
1763 solid waste disposal in deep repositories: Considerable uncertainties surround  
1764 exposures taking place in the far future. Thus dose estimates should not be  
1765 regarded as measures of health detriment beyond times of around several  
1766 hundreds of years into the future. Rather, they represent indicators of the  
1767 protection afforded by the disposal system. The Commission has given specific  
1768 guidance for the disposal of long-lived solid radioactive waste in Publication 81  
1769 (ICRP, 1998b). This guidance remains valid."

1770 Para 267: The principles of constructing and analysing scenarios are well known  
1771 and are often used in engineering. Their application was discussed in Publication  
1772 76 (ICRP, 1997b). Decisions on the acceptability of potential exposures should  
1773 take account of both the probability of occurrence of the exposure and its  
1774 magnitude. In some circumstances, decisions can be made by separate  
1775 consideration of these two factors. In other circumstances, it is useful to consider  
1776 the individual probability of -related death, rather than the effective dose (ICRP,  
1777 1997b). For this purpose, the probability is defined as the product of the  
1778 probability of incurring the dose in a year and the lifetime probability of -related  
1779 death from the dose conditional on the dose being incurred. The resulting  
1780 probability can then be compared with a risk constraint. If the probability is lower  
1781 than the risk constraint, it may be tolerated. Both of these approaches are  
1782 discussed in the Commission's Recommendations for the disposal of long-lived  
1783 solid radioactive waste in Publication 81 (ICRP, 1998b).

1784 Para 268: Risk constraints, like dose constraints, are source-related and in  
1785 principle should equate to a similar health risk to that implied by the  
1786 corresponding dose constraints for the same source. However, there can be large  
1787 uncertainties in estimations of the probability of an unsafe situation and the

1788 *resulting dose. Thus, it will often be sufficient to use a generic value for a risk*  
1789 *constraint. In the case of workers, this could be based on generalisations about*  
1790 *normal occupational exposures, rather than on a more specific study of the*  
1791 *particular operation. Where the Commission's system of dose limitation has been*  
1792 *applied and protection is optimised, annual occupational effective doses to an*  
1793 *average individual may be as high as about 5 mSv in certain selected types of*  
1794 *operation (UNSCEAR, 2000). For potential exposures of **workers**, the*  
1795 *Commission therefore continues to recommend a generic **risk constraint of  $2 \cdot 10^{-4}$***   
1796 *per year which is similar to the probability of fatal cancer associated with an*  
1797 *average occupational annual dose of 5 mSv (ICRP, 1997b). For potential*  
1798 *exposures of the **public**, the Commission continues to recommend a **risk***  
1799 ***constraint of  $1 \cdot 10^{-5}$**  per year.*

1800  
1801 Both dose and risk constraints should be applied in planned exposure situations.  
1802 For the specific situation of waste disposal dose constraints can be used for  
1803 comparison of options for normal releases, referred as “desing-basis evolution” of  
1804 the depository facility. Events with lower probabilities than the desing-basis  
1805 evolution should be treated as potential exposures and would require the  
1806 application of relevant risk constraints. Risk constraints will be applied either in an  
1807 aggregated or a disaggregated way.

1808  
1809  
1810

1811 **Annex 3 Technical and management principles and requirements**

1812

1813 Ref.: ICRP 101 section 6.6.4, §315, 316 ff

1814

1815 The general implementation of the Commission's recommendations on the disposal  
1816 of radioactive waste requires that organizational and managerial structures and  
1817 processes are put into place, and that technical principles are applied. Organizational  
1818 structures and processes can largely differ from country to country, but should be  
1819 based on the principles laid down by the IAEA in its Fundamental Safety Principles.

1820

1821 The Commission recommends that management principles and requirements should  
1822 be applied to the disposal system development and implementation process to  
1823 enhance the confidence that the protection of humans and the environment will be  
1824 ensured for as long as needed.

1825

1826 Management systems play an important role "to improve the safety performance of  
1827 the organization through the planning, control and supervision of safety related  
1828 activities in normal, transient and emergency situations" and "to foster and support  
1829 strong safety culture through the development and reinforcement of good attitudes  
1830 and behaviour in individuals and teams so as to allow them to carry out their tasks  
1831 safely" (IAEA GS-R-3).

1832

1833 The general requirements for establishing, implementing, assessing and continually  
1834 improving a management system have been formulated by IAEA, and specific  
1835 recommendations for the management system for the disposal of radioactive waste  
1836 in IAEA Safety Standards publication GS-G-3.4.

1837

1838 A management system designed to fulfill the international IAEA requirements  
1839 integrates safety, health, environmental, security, quality and economic elements,  
1840 with safety being the fundamental principle upon which the management system is  
1841 based. "The main aim of the management system shall be to achieve and enhance  
1842 safety by:

1843

- 1844 - *bringing together in a coherent manner all the requirements for managing the*  
1845 *organization;*
- 1846 - *describing the planned and systematic actions necessary to provide adequate*  
1847 *confidence that all these requirements are satisfied;*
- 1848 - *ensuring that health, environmental, security, quality and economical*  
1849 *requirements are not considered separately from safety requirements, to help*  
1850 *preclude their possible negative impact on safety."* (IAEA GSG-3.4)

1851

1852 Maintaining and further developing knowledge, competences and skills for the  
1853 disposal of radioactive waste, as an essential element to ensure high levels of safety,  
1854 should be based on a combination of scientific research and technological  
1855 development, insights gained from successive safety cases, learning through  
1856 operational experience and technical cooperation between all actors. Independent  
1857 reviews, transparency and accessibility of information, and openness to stakeholder  
1858 participation are also important contributors for ensuring high levels of safety.

1859

1860 A key technical principle for developing disposal systems and assessing their safety  
1861 is the concept of defence in depth which provides for successive passive safety  
1862 measures, enhancing the confidence that the disposal system is robust and has an  
1863 adequate margin of safety. The defence in depth concept as applied to disposal  
1864 systems imposes that safety is provided by means of the various components of the  
1865 system contributing to fulfilling the main safety functions in different ways over  
1866 different timescales. The performance of the various components contributing to  
1867 fulfilling the main safety functions has to be achieved by diverse physical and  
1868 chemical processes, such that the overall performance of the system will not be  
1869 unduly dependent on a single component or function. The main safety objective of  
1870 the siting (a.o. selecting the natural barrier system and its environment) and  
1871 designing (a.o. developing the man-made barrier system, taking due account of the  
1872 site characteristics) of a disposal system is to ensure that post-closure safety will be  
1873 provided by means of multiple safety functions and that even if a component or  
1874 safety feature does not perform fully as expected, a sufficient margin of safety will  
1875 remain.