CONSULTATION DOCUMENT

HPA ADVICE ON RADIOLOGICAL PROTECTION OBJECTIVES FOR THE LAND-BASED DISPOSAL OF SOLID RADIOACTIVE WASTE

ABSTRACT

HPA is revising its advice on solid radioactive waste disposal and this consultative document describes the proposed new advice. The new advice will replace the advice published in 1992 by the National Radiological Protection Board (which joined the Health Protection Agency in April 2005). There are two main reasons for going out for consultation on this topic now. First, the previous advice was based on recommendations from the International Commission on Radiological Protection (ICRP) which has recently updated its recommendations (ICRP, 2007). Second, there have been a number of recent policy reviews by the UK Government and others looking at the options for radioactive waste disposal.

The advice is intended for the detailed risk assessment of solid radioactive waste disposal facilities at the planning stage. Given the long half-life of some radioactive wastes, an important principle behind the proposed advice is that people in the future should have the same level of protection as people have today. The primary focus of the advice is therefore on the situation after the facility has closed rather than the operational period when it is receiving waste for disposal.

The key proposals for consultation include:

Criteria and methods for assessing the radiation risks from natural processes and events that could affect the waste disposal facility in the future.

Criteria for assessing the doses to people inadvertently intruding into the facility far in the future. Different approaches are proposed for intrusion into near surface disposal facilities, compared to those used to assess intrusion into deep geologic facilities.

Eleven questions are posed in the document. Responses should be sent to SolidWasteDisposal@hpa.org.uk to arrive no later than **3rd June 2008.**

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The following amendments have been made to this document since its first publication (March 2008)

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Page number 13 In the twelfth line of the second paragraph 'available from (Miles et al, 2007) or the UKradon website (BGS and HPA, 2007)' has been amended to 'available from (Wrixon et al, 1988)'.

The following references have been deleted from Section 13

Miles JCH, Appleton JD, Rees DM et al (2007). *Indicative Atlas of Radon in England and Wales*. Chilton, HPA-RPD-033.

BGS and HPA (2007). [Web page] UKradon - Radon Risk Reports. Available at http://www.ukradon.org.uk/ [accessed 12-04-2007].

The following reference has been added to Section 13

Wrixon AD, Green BMR, Lomas PR et al (1988). Natural radiation exposure in UK dwellings. Chilton, NRPB R-190.

CONTENTS

PURPOSE OF CONSULTATION

In 1992, the National Radiological Protection Board (NRPB) (NRPB, 1992) – now the Radiation Protection Division of the Health Protection Agency – published guidance on the application of the International Commission on Radiation Protection (ICRP) system of protection (ICRP, 1991) to the disposal of solid radioactive waste.

HPA now considers that the advice given in the Board Statement on the radiological protection objectives for the land-based disposal of solid radioactive wastes (NRPB, 1992) requires updating in the light of the recently published ICRP recommendations (ICRP, 2007) and other relevant publications by the International Atomic Energy Agency (IAEA) and the UK Environment Agencies, as discussed in the following sections.

HPA also considers that it is timely to review and update its advice now that the UK Government and devolved administrations'* Managing Radioactive Waste Safely (MRWS) programme for high and intermediate level waste (Defra et al, 2001) is entering Stage 3, its implementation phase. As part of Stage 2 of MRWS, the Committee on Radioactive Waste Management (CoRWM) advised that a programme of robust interim storage followed by geological disposal would be the best approach for the long-term management of this type of waste (CoRWM, 2006). The UK Government and devolved administrations has adopted these recommendations and has outlined how it intends to implement the long-term management of intermediate and high level waste (Defra et al, 2006a). The UK Government, the Welsh Assembly Government and the Northern Ireland Assembly Government† are currently developing a framework for implementing geological disposal (Defra et al, 2007b). In addition the UK Government and devolved administrations have recently revised their policy on the long-term management of low level waste (Defra et al, 2007a), including near surface disposal as an option for low level waste and very low level waste.

HPA maintains a neutral position on the issue of nuclear power generation and its waste.

Views are invited on the proposals set out in this consultation document. Specific questions for respondents to consider are included throughout the document and are listed together in Section 9. However comments are welcomed on all aspects. Section 10 includes details of how to respond to the consultation and Section 11 gives information on the next stages in the process. Please give your reasons in your responses to the questions.

This document has been prepared by Shelly Mobbs and Kelly Jones. The authors would also like to thank Tracey Anderson for her help in the preparation of this document.

* Department for Environment, Food and Rural affairs, Scottish Executive, Welsh Assembly Government and Northern Ireland Department of the Environment

† The Scottish Executive did not sponsor the consultation following the announcement on 25th June 2007 that the Scottish government does not accept that geological disposal is the right way forward. See http://www.scotland.gov.uk/News/Releases/2007/06/25101822

1 SUMMARY OF EXISTING RADIOLOGICAL ADVICE

1.1 Previous NRPB and HPA advice on disposal of solid radioactive waste

In 1992 the National Radiological Protection Board (NRPB) published a statement on radiological protection objectives for the land-based disposal of solid radioactive waste (NRPB, 1992). NRPB recommended that for the post-closure phase, the individual risk* to an average member of the critical group, attributable to any single disposal facility for solid radioactive waste, should not exceed a risk constraint of 1 in 100 000 per year. NRPB further recommended a design target for a single waste disposal facility of 1 in 1 000 000 per year (a risk level which is generally regarded as being of little concern). When this document (NRPB, 1992) was published, the ICRP's estimate of the risk of harm caused by radiation was about 0.06 per Sv (comprised of 0.05 per Sv for the risk of fatal cancer to an individual and 0.01 per Sv for the risk of serious hereditary disease in all subsequent generations). In its response to ICRP's 1990 recommendations (NRPB, 1993), NRPB had also recommended a dose constraint for members of the public of 0.3 mSv per year from a new source, where a source is defined as one or more practices under common management. Since this is equivalent to a risk of the order of 1 in 100 000 per year, the risk constraint proposed by NRPB for solid waste disposal was therefore broadly consistent with the dose constraint recommended for discharges.

The 1992 NRPB advice also contained discussion on the calculation of individual risk in future time frames, the treatment of uncertainty, the presentation of results and the optimisation of protection. The NRPB advice was adopted by HPA when NRPB became part of HPA in 2005.

1.2 Environment Agencies

The authorising departments†, together with the Food Standards Agency (FSA) and NRPB, have produced guidance on dose calculations for discharges of wastes in their Principles document (Environment Agency et al, 2002a). This specifies that the effective dose to a representative member of the critical group from controlled discharges from a facility should not exceed a source-related constraint. The constraints are defined in the Radioactive Substance Directions (GB Parliament, 2000b) as 0.3 mSv per year from any source and 0.5 mSv per year from the discharges from any site (see glossary for the definitions of source and site). For solid waste disposal, the authorising departments issued guidance on requirements for authorisation (Environment Agency et al, 1996) in 1997 and are currently updating this document. It contains a number of principles and requirements that the facility should address, eg sound engineering, independence of safety from controls, optimisation, and specifies a

* Where risk is defined as the probability of harm eg fatal cancer in a year

† The Environment Agency (EA), the Scottish Environment Protection Agency (SEPA) and the Department of the Environment In Northern Ireland (DoENI)

numerical criterion for the radiological impact after control is withdrawn from the site. The criterion is that the assessed radiological risk from the facility to a representative member of the potentially exposed group at greatest risk should be consistent with a risk target of 10^{-6} per year (ie 1 in 1 000 000 per year). The EA guidance document explains that this risk target is not the only criterion to be addressed and that a repository that just fails to meet the target may be acceptable if the other requirements are met.

1.3 International Commission on Radiological Protection

In 1998 ICRP published recommendations specifically for solid waste disposal (ICRP, 1998). The main focus of the document is on the long term, post-closure phase but ICRP also recommended that "…the optimisation principle should be applied in an iterative manner during the disposal system development process and should particularly cover both the site selection and the repository design phases". For the post-closure phase, ICRP considered that there are two broad categories of exposure situations to be assessed: natural processes and inadvertent human intrusion. (Intentional intrusion in full knowledge of the site was not included as this would be considered in the future by anyone planning intrusion). The document discussed the uncertainties inherent in assessments over long timescales and the difficulty in estimating the probabilities of possible inadvertent intrusion into the site in the future and recommended that natural processes and inadvertent human intrusion should be treated separately in a radiological assessment. For natural processes, which include all processes that lead to the exposure of individuals other than inadvertent human intrusion eg migration with groundwater, ICRP recommended that assessed doses or risks should be compared with a constraint of no more than about 0.3 mSv per year or its risk equivalent of around 10^{-5} per year. For inadvertent human intrusion, ICRP recommended that reasonable efforts should be made at the repository development stage to reduce the probability of inadvertent human intrusion or to limit its consequences if the assessed doses to those living around the site following inadvertent intrusion were sufficiently high that intervention (based on current criteria) would almost always be justified. In a related document on prolonged exposure situations ICRP (ICRP, 2000) gave advice on the level of dose to which this corresponds. ICRP advised that, in situations where people are already being exposed over several years, an annual dose of around 10 mSv may be used as a generic level below which intervention is not likely to be justifiable and an annual dose of around 100 mSv as a generic level above which intervention should almost always be justifiable.

ICRP also recognised the basic principle that individuals and populations in the future should be afforded at least the same level of protection as the current generation.

In 2007 ICRP issued new recommendations (ICRP, 2007), updating the 1990 recommendations (ICRP, 1991). The system of radiological protection described in these new recommendations is still based on the same three fundamental general principles given in the 1990 recommendations:

- Any decision that alters the radiation exposure situation should do more good than harm (*justification – source-related principle for all exposure situations).*

- The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors (*optimisation – source-related principle for all exposure situations)*.

- The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission (*dose limitation – individual-related principle for planned situations)*.

The other main features of these new recommendations which are relevant to this document are as follows.

- ICRP has reviewed the risk from radiation, and updated the radiation and tissue weighting factors and the concept of radiation detriment. The total risk of radiation detriment (allowing for loss of life expectancy and non-fatal cancers) for a typical population of all ages is now estimated to be 0.057 per Sv. The estimate of the risk of fatal cancer is now estimated to be 0.055 per Sv.

- ICRP has discarded the process-based protection approach using practices and interventions, and has moved to a situation-based approach applying the same source-related principles to all controllable exposure situations:

  - Planned exposure situations. These are situations involving the deliberate introduction and operation of sources. Planned exposure situations may give rise both to exposures that are anticipated to occur (normal exposures) and to exposures that are not anticipated to occur (potential exposures).

  - Emergency exposure situations. These are situations that may occur during the operation of a planned situation, or from a malicious act, or from any other unexpected situation and require urgent action in order to avoid or reduce undesirable consequences.

  - Existing exposure situations. These are exposure situations that already exist when a decision on control has to be taken, including prolonged exposure situations after emergencies.

- ICRP has maintained the dose limits for application in planned exposure situations at the same values as those previously applied to practices.

- ICRP has reinforced the principle of the optimisation of protection, which should be applicable in the same way to all exposure situations with restrictions on individual doses, called dose constraints for planned exposure situations and reference levels for emergency and existing exposure situations.

- ICRP confirmed that its previous advice on solid waste disposal and prolonged exposures, given in ICRP Publication 81 and ICRP Publication 82, is still valid.

In a planned exposure situation as described by ICRP (ICRP, 2007), a certain level of exposure is reasonably expected to occur. However, higher exposures may arise following deviations from planned operating procedures. ICRP refers to these as potential exposures (ICRP, 1997a). ICRP states that potential exposures should be considered at the planning stage of the introduction of a planned exposure situation. It states that it should be recognised that the potential for exposures may lead to actions both to reduce the probability of the events occurring, and to limit and reduce the exposure (mitigation) if any event were to occur. For potential exposures that could occur far in the future and where doses would be delivered over long periods, eg situations relevant to solid waste disposal in deep geological disposal facilities, ICRP comments that considerable uncertainties surround the exposure estimates. Thus dose estimates should not be regarded as measures of health detriment beyond timescales of around several hundreds of years into the future. Rather, they represent indicators of the protection afforded by the disposal system. ICRP (ICRP, 1998) recommended that the objective of protecting individuals from exposures is best achieved by considering both the probability of occurrence and the magnitude of these exposures.

The new 2007 ICRP recommendations are not discussed in detail here as HPA's response to the revised advice will be published elsewhere (HPA, to be published).

1.4 International Atomic Energy Authority

IAEA has produced a series of documents related to the management of radioactive waste. The Principles of Radioactive Waste Management (IAEA, 1995) discussed the basic objectives, concepts and principles. The IAEA document on the Geological Disposal of Radioactive Waste (IAEA, 2006) established the requirements relating to the disposal of radioactive waste in geological disposal facilities, for the operational and post-closure phases. The draft IAEA document on the Disposal of Radioactive Waste (IAEA, to be published) is intended to form the basis of the safety requirements relating to the disposal of all types of radioactive waste. It sets out the radiological protection criteria specified for the post-closure period, derived from the recommendations of the ICRP ((ICRP, 1991), (ICRP, 1997b), (ICRP, 1998)) that were summarised in Section 1.3 above.

For the operational phase of a disposal facility the draft IAEA document (IAEA, to be published) states that the safety requirements are the same as for any other nuclear facility. These are set out in the IAEA Basic Safety Standards (IAEA, 1996).

IAEA has also supported an extensive programme of work on assessment methodologies for estimating radiological impact in the post-closure period (IAEA, 2003; IAEA, 2004b; Koehler et al, 1991).

IAEA has also specified criteria for exemption of radioactive material from regulatory control and given guidance on clearance and exemption levels (IAEA, 1988; IAEA, 2004a).

2 SCOPE OF THE HPA ADVICE

The scope of the updated HPA advice will be restricted to radiological risks and the protection of human health, as in the previous advice. Formal advice on the chemical hazards associated with radioactive waste is not addressed in this document, although HPA will continue to provide general guidance as required. Radiological protection of non-human species will also not be addressed in this document because it is outside the remit of HPA.

The advice will apply to all types of solid radioactive waste, including wastes which arise in liquid or gaseous form but are converted to solids prior to disposal. It is intended that this advice should apply to all types of disposal facilities for solid radioactive waste that are consistent with current UK Government waste management policy (Defra et al, 2007a; Defra et al, 2007b). These range from purpose built facilities for radioactive waste near surface or deep underground, to existing landfill sites that accept small quantities of Low Level or Very Low Level waste. Disposal of exempt waste is not included in the scope of this advice.

It is important to realise that the HPA advice addresses radiological protection objectives that are intended to be applied at the planning stage of the disposal facility. The objectives are not intended to be applied to exposures if they occur in the future as this would then be an existing exposure situation and would be dealt with as such, at the time. The overall purpose of the advice follows the basic principles of radiation protection, namely to prevent harmful health effects (called tissue reactions or serious deterministic effects by ICRP) and to minimise exposures which could lead to cancer and heritable effects (called stochastic effects by ICRP).

The scope of this advice *will be similar* to the previous advice in that it:

- will consider the radiological protection objectives in terms of human health;
- will not consider the risks from chemicals or the effects on non-human biota;
- will apply to all types of solid radioactive waste; and
- will consider more than one disposal facility on the same site.

The scope of this advice *will differ* from previous advice in that it:

- will apply to all types of disposal facilities that can be used for solid radioactive wastes, according to current government policy (Defra et al, 2007a; Defra et al, 2007b).

The previous advice was intended only to apply to deep and shallow engineered disposal facilities constructed specifically for radioactive waste disposal.

3 REPOSITORY TIMELINE

It is useful to consider the timeline of a disposal facility that accepts solid radioactive waste. From the radiological protection point of view, four distinct phases can be identified. The first is the operational phase, covering the period after the construction of the disposal facility when it is receiving radioactive waste. This will start when authorisation for disposal has been received from the relevant authorising department and will end when the disposal facility is full and has been closed. Closure of the disposal facility may be progressive since the disposal facility may have sections at different stages, some under construction, some receiving waste and some closed. It may also be designed for phased disposal, as defined by the Government's Committee on Radioactive Waste Management (CoRWM), enabling it to stay open and function as a storage facility for several hundred years. Depending on the design of the disposal facility closure can take different forms, such as capping (landfill site) or backfilling and sealing (deep geologic facility). The operational phase may therefore last several decades or more, especially in the case of a deep geologic facility. The second stage is the active institutional control period which covers the time from closure of the disposal facility to the time when active care and maintenance of the site ceases after several decades or more. It is not reasonable to expect that active care and maintenance of the site will be possible forever and therefore it is assumed that it will cease at sometime in future, either as a result of a review of the hazard potential of the site or as a result of changed priorities or lack of resources. The site then enters the third phase, the passive control period, when records are expected to inform future generations of the presence of the radioactive waste. Eventually, it could be expected that the records will become lost and this marks the end of the passive control period and the start of the fourth and final period, the uncontrolled phase.

Obviously the length of time spent in each stage will depend on the type of facility and the properties of the waste disposed, in particular its half-life. Some stages have definite endpoints, others are more vague and judgement has to be used in estimating when they will occur.

The primary focus of this advice is on the *post-closure* period for existing and future *purpose-built* radioactive waste disposal facilities for solid radioactive waste (ie the second, third and fourth phases described above). However, landfill sites accepting other wastes are included and the pre-closure period is also briefly discussed.

4 OPERATIONAL PHASE

The radiological protection principles and criteria that apply to an operational nuclear facility also apply to the operational phase of a purpose built repository. Of particular relevance, therefore, are the occupational dose limits for workers specified in the Ionising Radiations Regulations (IRR99) (GB Parliament, 2000a) as these apply to workers at the repository. Currently, this means that a dose limit of 20 mSv (effective dose) per year applies to employees of 18 years of age and above working on the site, which is prescribed under IRR99 (GB Parliament, 2000a). For a non-purpose built disposal facility, eg a landfill site that also receives hazardous wastes, the dose limit for members of the public would apply to the operators at the site. This is currently 1 mSv (effective dose) per year (GB Parliament, 2000a).

Doses to the public as a result of discharges from the disposal site, whether purpose built or not, would need to be consistent with the latest publication of the UK National Strategy on Discharges (Defra, 2002) and satisfy the requirements of the OSPAR Convention (OSPAR Commission, 1992)*. The dose to members of the public due to discharges from any source and any site should be below the dose constraints of 0.3 mSv per year and 0.5 mSv per year respectively given in the Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000 (GB Parliament, 2000b). The total dose to an individual from past and planned discharges should also be below the annual dose limit for members of the public of 1 mSv. Also relevant are the Environment Agency's principles and criteria for assessing public doses due to discharges (Environment Agency et al, 2002b).

In the final conclusions of its review of radioactive waste management (Cm 2919) (Department of the Environment et al, 1995), the Government introduced a threshold or lower bound on optimisation for radioactive waste discharges, similar to the lower level defining broadly acceptable risk in HSE's tolerability of risk (TOR) document (HSE, 1992). The value for this threshold was set at 0.02 mSv per year, and can be broadly equated to an annual risk of death of about one in a million per year. If exposures are calculated to be below 0.02 mSv per year, the regulators are advised in Cm 2919 that they should not seek to secure further reductions in the exposure of members of the public, provided they are satisfied that the operator is using the best practicable means to limit discharges.

HPA supports this approach. It is important that the balance between the consequences of different waste management options for operational wastes is considered since optimisation of health protection does not necessarily mean minimisation of discharges.

5 POST-CLOSURE PHASE

5.1 Potential routes of exposure post-closure

There are many possible pathways by which humans may become exposed in the post-closure period. Internationally agreed assessment methodologies, eg BIOMOVS (Koehler et al, 1991), recommend that all the features, events and processes that could affect the repository are explicitly reviewed and that they are considered in the assessment of the radiological impact if they are relevant to the particular situation and

* This includes the requirement to ensure that by the year 2020 discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, are close to zero

context being assessed. HPA proposes that it is helpful to divide the potential exposure routes into three categories: natural processes; natural events; and human intrusion.

5.2 Natural processes

This category is intended to capture natural processes that are almost certain to occur given the timescales that will be considered for some of the long-lived radioactive wastes (eg groundwater driven flow of radioactive contaminants from the disposal facility, climate change effects, uplift and subsidence) and that have gradual, continuous interactions with the system being modelled. Although climate change and uplift/subsidence can be regarded as gradual processes they can potentially give rise to abrupt environmental changes. These would be classed as natural events and are dealt with in the section below.

5.3 Natural events

This category is intended to represent natural occurrences that have a specific starting time, and usually, a duration shorter than that of natural processes or simulated in a model. It will include uncertain occurrences that take place within a short time relative to the time frame of the models eg volcanic activity, seismic activity, flooding, landslips and tsunamis.

5.4 Human intrusion

This category is intended to represent human actions that result in intrusion into the radioactive waste by bypassing one or more of the barriers designed to keep the radioactive waste away from humans. Two broad types of intrusion could occur:

- Intentional – deliberate intrusion into a facility in the full knowledge of its presence and its contents, for good or bad intent; or
- Inadvertent – accidental intrusion into a facility resulting from a loss of knowledge or understanding of its presence and its contents.

The first type could include actions to deliberately retrieve the waste or actions to deliberately compromise the safety of the disposal facility eg terrorist attack. In the former case the actions would be planned and managed. In the latter the consequences for the deliberate intruder are primarily considered the intruder's responsibility and existing procedures for dealing with the consequences of terrorist attack would come into play. It is widely accepted that although the society that creates radioactive waste should bear responsibility for developing a safe disposal system that takes into account future societies, the current society cannot protect future societies from their own actions if they (the future society) are forewarned of the consequences.

Therefore only the second type of intrusion, inadvertent intrusion, is considered in this document. Inadvertent intrusion could occur into the disposal facility itself or into the plume of radioactive contamination in the geosphere formed by the radionuclides gradually migrating from the waste disposal facility. This inadvertent intrusion could degrade the environmental safety performance of the facility. For this purpose, it will be assumed that a future society has similar skills and knowledge to those of the present day.

A third type of intrusion, naïve intrusion, can also be considered. This represents deliberate intrusion where the intruder does not have full knowledge of the likely consequences, eg archaeologists. HPA proposes that naïve intrusion is covered by the concept of inadvertent intrusion and does not need separate consideration.

Question 1: **HPA has categorised the exposure routes that should be assessed into three broad types: natural processes, natural events and inadvertent human intrusion. Are there other categories of exposure routes which HPA should consider?**

6 RADIOLOGICAL PROTECTION OBJECTIVES

6.1 Basic principles

The basic principles of radiological protection remain unchanged in the new ICRP recommendations. They are justification, optimisation and dose limitation. The primary aims are prevention of deterministic effects (now called tissue reactions) and minimisation of stochastic effects. The latter is achieved by optimisation: keeping doses or risks as far below a dose or risk constraint as reasonable, economic and social factors being taken into account. In view of the long term nature of waste management further, ethical, principles also apply. The IAEA safety standard for waste management (IAEA, 1995) gives 9 principles; other relevant principles are the minimisation of waste, the proximity principle and precautionary approaches and principles. Many of these have been incorporated in UK waste management policy and HPA is supportive of this. From the radiological protection viewpoint, the most important principle for radioactive waste disposal is that of protecting future generations to the standard that we accept today.

6.2 Health impacts

The radiological protection objectives for waste management recommended by ICRP (ICRP, 1998) are in terms of dose and in terms of risk, depending on the type of situation being considered. As discussed below, HPA also intends to recommend criteria in terms of both dose and risk. The relationship between the two is defined here:

$$R = \gamma \sum_i p_i E_i$$

where R is the excess risk of harm, eg cancer, in the year considered;

γ is the excess risk of harm, eg cancer, per unit effective dose (Sv^{-1});

p_i is the probability of scenario i, which if it occurs gives rise to an effective dose of E_i in the year considered;

E_i is the effective dose in a given year (Sv) resulting from an event, defined to be the sum of the effective dose from external exposure during that year and the committed effective dose from intakes of radionuclides during that year resulting from the event.

The above equation is valid when the risk associated with effective dose is linearly related to the dose. This linear relationship is valid up to a particular level of effective dose: for leukaemia, for example, the trend would be non-linear for acute doses above 0.1 Sv; however it may still be linear for protracted exposures at this level of exposure. The maximum level of effective dose at which the linear relationship can be considered valid is currently being addressed by ICRP. For the purposes of waste management disposal assessments the equation should be used for annual effective doses less than 0.1Sv. The risk associated with acute effective doses above 0.1 Sv may not be linearly related to the dose and therefore should be calculated separately.

The new ICRP recommendations (ICRP, 2007) give risk coefficients (γ) for two different measures of harm: detriment and fatal cancer. Detriment includes the weighted probability of attributable non-fatal cancers and the length of life lost as well as the probability of attributable fatal cancers and the weighted probability of severe heritable effects in all subsequent generations (the latter is represented by the risk factor for the next two generations). The previous advice (NRPB, 1992) used the risk coefficient (γ) corresponding to the probability of fatal cancer occurring in an individual or of a serious deleterious hereditary effect in his/her descendents as a result of exposure to ionising radiation, taken from ICRP's 1990 recommendations (ICRP, 1991). It did not consider the total risk of detriment (allowing for loss of life expectancy and non-fatal cancers).

It is proposed that the HPA advice should adopt the new detriment-adjusted risk coefficient proposed by the new ICRP recommendations (ICRP, 2007). The estimate of the detriment-adjusted risk coefficient for the whole population is given in the new ICRP recommendations as 0.057 per Sv. HPA proposes that the rounded value of 0.06 per Sv be used for waste management assessments. It should be noted that, for the purposes of radiological protection, the risk coefficient for fatal cancer for the whole population given in the new ICRP recommendations (ICRP, 2007) is 0.05 per Sv. This is not significantly different from the detriment-adjusted risk coefficient, given all the other uncertainties inherent in assessments of the radiological impact of waste disposal. Therefore the risk of detriment could also be used to estimate a number of fatalities for comparison purposes.

The CERRIE report (CERRIE, 2004) recommends that the uncertainty in the dose and risk estimates needs to be considered, particularly with respect to internal doses and risks. HPA agrees with this recommendation. HPA's view is that the degree of uncertainty associated with ICRP dose coefficients varies with the radionuclide. For some radionuclides, eg isotopes of caesium and iodine, the uncertainties are of the order of two to three, but for other radionuclides, eg isotopes of plutonium, the uncertainties can in certain circumstances exceed a factor of ten.

Question 2: What measures of health impact(s) should HPA consider for assessing the radiological impact of repositories post-closure: dose, detriment-adjusted risk or fatal cancer risk?

6.3 Criteria for natural processes and events

HPA proposes the use of a risk constraint for natural processes and events, ie both the probability of the scenario occurring and its consequences are to be considered. For natural processes and events it is proposed that an annual risk constraint of detriment of 1 in 100 000 per year is used. This annual risk constraint applies irrespective of whether the exposure is received over a few weeks or remains roughly constant over decades or more. This is broadly equivalent to the dose constraint resulting from a defined source for use at the planning stage ie currently 0.3 mSv per year in the UK legislation (GB Parliament, 2000b) using the detriment-adjusted risk coefficient of 0.06 per Sv recommended in the new ICRP recommendations (ICRP, 2007)[*]. Hence there is continuity in radiological protection standards from the operational to post-closure phases.

Although the criterion is specified in terms of risk, HPA proposes that the dose and associated probability should also be presented to aid understanding of the main contributions to the risk.

In line with basic philosophy of radiological protection, meeting this risk constraint is not sufficient in itself: optimisation is required to reduce the risk to a value below this risk constraint, economic and social factors being taken into account. Conversely, this risk constraint should not be viewed as a limit but as a factor in the optimisation process.

Previous advice (NRPB, 1992) specified a risk constraint of 1 in 100 000 per year to an average member of the critical group attributable to a single waste disposal facility. It should be noted that this constraint applied to the total risk, ie it included the risk from human intrusion as well as the risk from naturally occurring events and processes. HPA is now proposing to set separate criteria for intrusion, see Section 6.4.

The previous advice also stated that if two or more disposal facilities are planned on the same site under common management, then the constraint should apply to the sum of risks from the disposal facilities. It is proposed that this advice is clarified to recommend that the constraint applies to the sum of risks from the facility and any other existing or planned disposal facility that also affects the same exposure group at the same time. In other words, the summation should be done taking into account any differences in the exposure groups and the times of exposure. Hence risks occurring at completely different times or to completely different groups would not be summed.

[*] Strictly 0.3mSv equates to a risk of 2 10^{-5} but in view of the uncertainties inherent in estimates of doses over long timescales the criterion is rounded down to the nearest order of magnitude

Question 3: **HPA has proposed a risk constraint of 1 in 100 000 per year for natural processes and events. Do you agree with this value? If not, why not? Should the risk constraint be set for a single facility or all disposal facilities affecting the same exposure group at the same time?**

Doses and risks arising from the build up of radon in buildings should be treated separately as there are separate national standards for the total level of radon in dwellings and workplaces. For dwellings previous advice gives an Action Level for radon of 200 Bq m^{-3} (NRPB, 1990) and this has been endorsed by Government (Department of the Environment, 1990). For workplaces employers are required by the Management of Health and Safety Regulations at Work 1999 (GB Parliament, 1999) to assess risks from radon in workplaces in Radon Affected Areas[*], and this usually requires a measurement. The Ionising Radiations Regulations 1999 (GB Parliament, 2000a) generally require action to protect employees if the average radon gas concentration exceeds 400 Bq m^{-3}.

Since the level of radon in a building can vary by over an order of magnitude depending on the characteristics of the building, the habits of the occupants and the geological characteristics of the ground underneath the building it is very difficult to estimate the level of radon in a building simply on the basis of the radium content of the soil. Hence the level of control needed against radon exposure, if any, is actually determined by taking measurements in the building of interest. From the point of view of assessing the radiological impact of radioactive waste disposal, the level of radon measured in a building would be comprised of radon from naturally occurring radionuclides in the soil as well as any radon originating from any disposed radioactive waste that had migrated to that location. HPA therefore considers that the radon concentration arising from the waste should be estimated and compared with the indicative radon level for that area, available from (Wrixon et al, 1988) and the appropriate national standard.

Doses leading to deterministic effects might occur in a scenario whereby intermediate or high level waste is brought to the surface by some dramatic environmental event. For a deep repository, the probability of this scenario is very low and it would therefore not be sensible to modify repository design solely to limit the consequences of such an event, particularly if the modification might detract from the performance of the repository in 'normal' situations.

Previous advice (NRPB, 1992) applied a probability constraint to all *naturally occurring* events (ie not human intrusion) in order to avoid doses capable of causing deterministic effects whenever possible. For an individual in a critical group, the previous advice recommended that the total probability of receiving a dose above 0.5 Sv (the approximate lower limit for deterministic effects) as a result of naturally occurring events should not exceed 1 in 1 000 000 per year. In light of the more recent information on the linearity of risk with dose (see Section 6.2), the overall uncertainty in estimates of dose in the long term and in the interests of mathematical simplicity, HPA proposes to

[*] The Health Protection Agency defines Radon Affected Areas as those with 1% probability or more of a home having radon above the Action Level.

modify the advice to recommend that the total probability of a person receiving a dose above 0.1 Sv as a result of naturally occurring events should not exceed 1 in 1 000 000 per year.

Naturally occurring sudden and catastrophic events whose non-radiological consequences on individuals and society would clearly outweigh any radiological consequences (eg a large meteorite impact) may be excluded from the calculated probability.

> ***Question 4:*** **Is the HPA proposal the best way to deal with prevention of doses giving deterministic health effects from natural events? If not, what would be a better approach?**

6.4 Criteria for inadvertent human intrusion

The probability of inadvertent human intrusion will vary depending on the main factors given below:

- depth of the disposal facility - it is believed that the risk from intrusion decreases as the depth of disposal increases as more effort would be required to access greater depths;
- nature of the waste - if the waste is long-lived there is a greater probability that at some time in the future intrusion will occur while the waste is still radioactive;
- nature of the geosphere - for example if the disposal facility is situated in crystalline rock as opposed to salt rock any potential intruder will have to expend greater effort and more resources in order to penetrate the disposal facility;
- siting in areas of low mineral resource potential - if there are low mineral resources in the area it is likely that there will be less drilling and exploration for mineral resources;
- knowledge of the presence of the site - the probability of intrusion will be very low when there is knowledge of the presence of the site eg passive institutional controls still exist such as records relating to the disposal facility or control of land use;
- presence of man-made structures – intrusion is less likely if the presence of man-made structures indicates the existence of the disposal facility or limits the capacity for land redevelopment; conversely, the presence of dilapidated structures might encourage redevelopment and therefore intrusion could be more likely;
- thickness and physical properties of the cover - the thicker and more durable the cover of the disposal facility, the less likely an intruder is to gain access to the waste;

- type of disposal site (purpose built or not) – intrusion is more likely in a site that is primarily used for other wastes and only accepts small quantities of radioactive waste than in a purpose built radioactive waste facility;
- area of site and contaminated plume in the geosphere – intrusion is more likely to occur if the area is very large;
- Level of technology – intrusion is more likely if technology is more advanced but, conversely, they are more likely to recognise the hazard and protect against it.

6.4.1 Near surface disposal facilities

It should be recognised that for near surface disposal facilities, especially ones that are not purpose built just for radioactive waste, it is probable that inadvertent human intrusion into the facility will occur at some stage during the next thousand years. However the probability of intrusion in any given year will be low and can be assumed to be zero during both the active and passive institutional control periods. Certain measures can be taken to reduce the annual probability of intrusion (such as the use of markers, the use of anti-intrusion barriers and the location of a disposal facility in a remote area), but such measures are only likely to delay rather than prevent intrusion into near surface disposal facilities. If only short-lived waste is present in the repository, this delay may be adequate to ensure that the intrusion may not result in significant doses. If the repository contains long-lived radionuclides in significant amounts, delay of the intrusion event for a few tens of years may have little or no impact on the received doses. Therefore the emphasis for protection of human health should be on mitigating the consequences of intrusion that could occur after the end of the passive institutional control period ie controls should be placed on the doses likely to be received.

Similar arguments can be made for inadvertent intrusion into the plume of radioactive contamination in the geosphere where, although there would be no markers or anti-intrusion barriers, the concentrations would be lower.

Since there is a large uncertainty associated with the probability of intrusion in a given time period, but there is the potential for high doses should intrusion occur, HPA proposes to set a dose criterion for inadvertent human intrusion rather than a risk criterion.

In deciding on the dose criterion, HPA considers that there are a number of parallels between prospective assessments of the situation that would arise if inadvertent intrusion were to happen, considerations of emergency exposures and considerations of existing exposure situations. There are essentially two aspects to inadvertent intrusion. The first is the potential transitory exposures that could be received by the intruder. This can be viewed in an equivalent way to planning for emergencies. Secondly, there is the potential widespread contamination of the environment following inadvertent intrusion, leading to prolonged exposures. This can be viewed as analogous to existing exposure situations.

HPA proposes to specify different dose criteria for transitory and prolonged exposures as a result of inadvertent intrusion. To avoid confusion with the terminology in the new ICRP recommendations, and recognising that there are many sources of uncertainty in performing dose calculations, HPA proposes to call these dose criteria for inadvertent intrusion ‘guidance levels’.

ICRP discusses three different dose bands (ICRP, 2007) from which it recommends that dose constraints and reference levels should be selected, the actual value depending on the type of situation being considered. The upper band, 20 mSv to 100 mSv, is considered appropriate "in unusual, and often extreme, situations", and may also be applied to "circumstances where benefits from the exposure are commensurately high." An example would be reference levels and constraints for life saving actions in a radiological emergency. The middle band, 1 mSv to 20 mSv, is appropriate when "individuals receive direct benefit from an exposure situation" but not necessarily from the exposure itself. Reference levels in this band can be applied "where there is individual surveillance or dose monitoring or assessment, and where individuals benefit from training or information." Examples of such a situation might be occupational exposure in a planned exposure situation, abnormally high levels of natural background radiation, or stages in post-accident rehabilitation. The lower band, below 1 mSv, is appropriate where the exposure is usually a planned one and the individual receives no direct benefit but "the exposure situation may be of benefit to society." Reference levels below 1 mSv can be applied when "there is general information and environmental surveillance or monitoring or assessment and where individuals may receive information but no training."

ICRP had previously suggested (ICRP, 1998; ICRP, 2000) that the reference level for prolonged exposures from contaminated land should be in the range 10 mSv -100 mSv, ie in the middle to upper bands. However, as discussed above, the more recent recommendations now support a dose in the range 1 mSv – 20 mSv. As mentioned previously, advice has also been provided on radon in homes, another existing prolonged exposure situation; a UK Action Level for radon in homes of 200 Bq m^{-3} was proposed (NRPB, 1990). This corresponds to exposures in the region of 10 mSv per year, in the middle ICRP band. The lower band has been used internationally for defining annual dose constraints and annual dose limits for members of the public (0.3 mSv and 1 mSv respectively) and for defining levels of radioactivity that are exempt from regulatory control (exemption levels), based on annual dose constraints of 0.01 mSv for normal situations and 1 mSv for unlikely situations (IAEA, 2004a).

HPA recently recommended that an annual dose criterion of 3 mSv should be used for the designation of radioactively contaminated land (HPA, 2006) in the recent extension of the contaminated land regulations to radioactively contaminated land (GB Parliament, 2007). This advice related specifically to situations involving prolonged exposure ie exposure that continues at broadly the same level for periods of the order of decades or longer. Hence, if intrusion into a near surface disposal facility does occur in the future then, under current radioactive land regulations, if residents receive a dose above 3 mSv per year for periods of the order of decades then the land could be designated as radioactively contaminated land. Remediation would need to be considered, but it might not in fact be undertaken if it was not found to be the optimum solution. It should be noted that this regime does not include radon gas ie the dose from exposure to radon gas in buildings is not included in the 3 mSv annual dose criterion for the designation of radioactively contaminated land.

HPA proposes a guidance level of 20 mSv (total dose) for transitory exposures where the length of exposure could vary from a few hours to a few weeks, eg for handling soil specimens taken from the disposal facility or contaminated plume in the geosphere. It should be noted that this is a guidance level for optimisation studies, not an absolute limit. However, if estimates of transitory exposure are above this level then HPA would expect a comprehensive optimisation study to be performed to consider ways to reduce the dose and/or the probability of receiving the dose. A disposal facility that is estimated to give rise to doses above the guidance level would therefore only be acceptable if it was shown to be the overall optimum solution. If estimates of transitory exposure are below the guidance level then optimisation can be limited to the design of the facility.

For prolonged exposures, eg exposure that continues for periods of decades or more of people who live on or near to a disposal facility which has subsequently been excavated resulting in contamination of the land, it is proposed that an annual dose guidance level of 3 mSv per year is specified. It can therefore be argued that future generations are being treated with the same consideration as the present generations: one of the IAEA principles of radioactive waste management (IAEA, 1995). Again, this criterion should be viewed as a guidance level for optimisation purposes, not as an absolute limit. As discussed above, if estimates of prolonged exposure are above this level then HPA would expect a comprehensive optimisation study to be performed to consider ways to reduce the dose and/or the probability of receiving the dose. A disposal facility that is estimated to give rise to doses above the guidance level would therefore only be acceptable if it was shown to be the overall optimum solution. If estimates of prolonged exposure are below the guidance level then optimisation can be limited to the design of the facility.

The case where exposures are estimated to continue for more than a few weeks but not to continue at roughly the same level for decades requires separate consideration. An example is exposure over a few years to a dose from a relatively short lived radionuclide. The dose rate may be at its highest at the start of the exposure period or it may peak after a year or so within a total exposure period of a decade or so. The question is then which dose criterion should apply to doses that are only received for a year or two? Furthermore, if inadvertent intrusion does occur then the fact that doses are being received may not be recognised as there is unlikely to be monitoring of the persons exposed. This is different to the situation in an emergency where the potential for receiving a dose is recognised and hence exposures can be assessed and managed. Hence it is reasonable to set lower dose criteria for inadvertent intrusion than for emergency planning. HPA considers that for waste management related assessments of exposures from human intrusion it is not appropriate to consider exposures that continue at roughly the same level for longer than 5 years as transient exposures. Taking a cautious approach, HPA proposes that the 3 mSv annual dose criterion should be applied to doses resulting from inadvertent intrusion that are received over a period of a year or more. However, an alternative option would be to apply the transient total dose criterion of 20 mSv to doses received over time periods of up to 5 years and the 3 mSv annual dose criterion for doses received over a period of 5 years or more. Views are welcomed on this issue, see question 5.

Again, in line with the national standards on radon in buildings, the exposure to radon gas should be considered separately, with the estimated concentrations compared with the indicative levels from naturally occurring radon and the appropriate national standard.

Concentrations in drinking water should also be compared with the levels specified in the drinking water directive (EC, 1998).

> ***Question 5:*** **HPA is proposing dose based criteria for calculations of inadvertent human intrusion into near surface disposal facilities. HPA proposes a dose guidance level of 20 mSv is used for short-term exposures and an annual dose guidance level of 3 mSv per year for exposures lasting more than 5 years. What dose criterion do you think should apply to exposures that last more than a few weeks but less than 5 years: the 20 mSv total dose, the 3 mSv annual dose or another value?**

In its previous advice HPA also recommended that the probability of receiving doses above 500 mSv (from natural events or human intrusion) should be kept below 1 in 1 000 000, in order to reduce the probability of receiving doses which could cause deterministic effects. HPA considers that it is most important to protect against serious deterministic effects. However, a guideline dose of 20 mSv (total transient dose) or 3mSv annual dose for inadvertent human intrusion will ensure that doses are well below the level that could give rise to serious deterministic effects. Hence, now that the criteria for inadvertent intrusion are specified in terms of dose rather than risk, it is not necessary to set a numerical criterion for the probability of inadvertent intrusion.

6.4.2 Deep geological disposal facilities

For deep geological disposal facilities, proposed by the UK Government for the management of the UK's higher activity waste, the potential for intrusion has already been reduced by placing the waste at depth. The process of site selection will also have reduced the potential for intrusion to be as low as reasonably possible, economic and social factors being taken into account, by selecting a site with a suitable geosphere and in an area of low mineral resource potential. Hence significant effort and technology would be required in order to intrude into the deep geological disposal facility. Although the potential for intrusion and resulting doses, including deterministic ones for higher activity waste, cannot be completely eliminated the principle of optimisation applies ie to show that all that can reasonably be done has been done. (This assumes that deliberate dilution of the waste to give lower activity concentrations and hence lower doses is not permitted, ie the current regulatory position). The new ICRP recommendations (ICRP, 2007) state that "Optimisation of protection is not minimisation of dose. Optimised protection is the result of an evaluation, which carefully balances the detriment from the exposure and the resources available for the protection of individuals. Thus the best option is not necessarily the one with the lowest dose". Therefore it is proposed that it is not useful to specify a dose constraint or dose guidance level. However it is still important that a few stylised scenarios are used to explore the range of likely probabilities of intrusion and the consequences of intrusion into a deep geological disposal facility and to demonstrate that protection has been optimised.

> ***Question 6:*** **HPA is proposing different approaches for deep geological and near surface disposal facilities for inadvertent human intrusion. For deep geological facilities it is proposed that no dose guidance level is set but that 'stylised scenarios' are used to explore the likely consequences. Do you have any comments on this proposed approach?**

6.5 Optimisation

The new ICRP recommendations (ICRP, 2007) continue to emphasize the key role of optimisation in radiological protection. In summary this means that the likelihood of incurring exposures, the number of people exposed and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and social factors. ICRP's intention is that the level of protection should be the best under the prevailing circumstances, maximising the margin of benefit over harm.

The previous advice (NRPB, 1992) stated that for the purposes of optimisation it should be remembered that it will also be necessary to consider factors relating to the design, construction and operational periods, such as costs and occupational doses, in addition to doses to the public in the post-closure phase. The advice also stated that society's perception of low consequence, high probability events tends to differ fundamentally from that of high consequence, low probability events. Therefore, when individual risks are used in optimisation studies, the probability and consequences should always be given separate consideration. HPA proposes to include these statements in the new advice. In addition HPA wishes to stress that optimisation does not mean minimisation; optimisation should balance the detriment against the resources available. Thus the overall best option may not necessarily be the one with the lowest estimated doses to future generations.

For all types of disposal facilities information must be provided on the estimated doses, probability of scenarios occurring and the likely risks arising. It is also important that the uncertainties in the calculations are clearly set out. Arguments as to the robustness of the data must be provided eg in some cases the probabilities of occurrence will be better understood than in others and the reasons must be highlighted. The purpose of clearly stating the factors that are considered in the calculation is so that improved understanding of important aspects and a comparison of different disposal options can be made. As the doses may be dependent on the time at which intrusion is assumed to occur, a number of different times should be investigated to scope the range of results.

6.5.1 Design target (lower guidance level)

HPA recognises that comprehensive and detailed optimisation studies for waste management options are resource intensive. However, if the radiological impact associated with the options is extremely small then inappropriate levels of effort could be expended on reducing trivial risks. Therefore the previous advice (NRPB, 1992) specified a risk level below which the optimisation requirement could be relaxed, called a 'design target'. The design target was set at a risk level that represents the lower bound below which the risk level is generally regarded as being of little concern, based on the HSE report on tolerability of risk (HSE, 1992). Thus, in its previous advice, NRPB recommended an appropriate design target for the risk to an average member of the critical group attributable to a single waste facility as 1 in 1 000 000 per year. If estimated doses from a disposal facility do *not* satisfy the design target, but the risk constraint is satisfied, then the facility may be licensed if it is demonstrated that the choice of disposal concept, disposal site and facility design represent the optimum management system for the wastes. If the estimated doses from the disposal system *do* satisfy the design target, then the optimisation requirement may be limited to the design of the facility.

HPA considers that the term ‘design target’ has not been well understood and now proposes to use the term ‘lower guidance level’ instead.

HSE revisited the concept of tolerability of risk in its 2001 document, Reducing Risk, Protecting People (HSE, 2001) and concluded that a risk of death of 1 in 1 000 000 per year is extremely small when compared to the risk accepted by people in their daily lives and should therefore be used as the boundary below which risks are broadly acceptable. HPA considers that overall risk perception has not changed significantly over the past few years and that a risk level of 1 in 1 000 000 per year is still appropriate for use as the boundary. HPA therefore proposes to continue to recommend that if the risks from natural events and processes are below the lower guidance level (design target) of 1 in 1 000 000 per year then the optimisation requirement can be relaxed as described above. The concept of a lower guidance level (design target) does not apply to human intrusion scenarios.

***Question 7:* Is the concept of a lower guidance level useful? If so, do you agree that it should be set at 1 in 1 000 000 per year? If not, why not?**

6.5.2 Collective doses

The main radiological input into optimisation studies has generally been the total (integrated) collective dose as a surrogate for the total health detriment incurred. However this is not always straightforward for waste management options because of the long timescales and uncertainties involved. The post-closure collective dose to members of the public is so dependent on detailed assumptions about the biosphere, human behaviour and population size that such calculations must be treated with extreme caution. An optimisation study requires parameters that enable the decision maker to differentiate between the different options and the uncertainties in the long term collective dose mean that this is not a useful discriminator.

In its 2006 publication on dose assessments for radiological protection and its optimisation (ICRP, 2006), ICRP gives some advice on the use of collective doses. In particular ICRP makes it clear that under certain circumstances it is inappropriate to use collective doses when optimising: "When the exposures occur over large populations, large geographical areas, and long periods of time, the total collective effective dose (ie the summation of all individual exposures in time and space) is not a useful tool for decision aiding because it may aggregate information excessively and could be misleading for selecting protective actions." ICRP states that collective effective dose is not intended as a tool for epidemiologic risk assessment, and it is inappropriate to use it in risk projections. In particular the calculation of the number of cancer deaths based on collective effective doses from trivial individual doses should be avoided. HPA concurs with this view for assessments of solid waste disposal.

In situations where collective doses are useful, the ICRP document advises on a move away from collective doses to ‘group’ doses, thus taking earlier guidance on disaggregation a step further. Essentially ICRP recommends that, in broad terms, the concept of collective dose is retained but within the context of a ‘dose matrix’. (Smith et al. 2006) have examined the guidance on the calculation, presentation and use of collective doses for routine discharges. The report concluded that collective doses to a limited number of population groups over various temporal periods could be determined, and this could go some way to providing the required breakdown of collective dose into different geographical regions and times for a dose matrix. At long time periods, however, the report found that the per-caput dose rate is similar for all geographical populations and hence there is little to be gained from the 'dose matrix' approach for times far into the future.

HPA considers that in optimisation studies for solid waste management options it is possible to consider the collective dose to workers and the public from operations and discharges during the operational and active institutional control phases, and to members of the public for about 500 years post-closure but that it is not advised to consider the very long term collective dose to members of the public in view of the large uncertainties. These uncertainties effectively make any comparison meaningless.

Question 8: **Is collective dose a useful concept for assessing the disposal options for long-lived waste: a) for the first 500 years post-closure? b) for the very long term? If not, why not?**

6.6 Other indicators

ICRP has suggested that dose is not the only indicator of the impact of a repository, especially in view of the long timescales and the uncertainty in the evolution of the biosphere (ICRP, 1998).

ICRP states that it may be useful to make qualitative comparisons particularly for the distant future, eg of the remaining hazard potential of a disposal system with the risk imposed by other natural or human-induced sources. Such comparisons may help to put judgements on the radiological acceptability of a disposal system in proper perspective. Other suggestions are to consider the flux of radionuclides from the geosphere to the biosphere rather than the dose. It should be remembered that the health impact is not necessarily directly proportional to every possible indicator that could be considered since some indicators are only important over short timescales and hence have only limited importance to the overall performance of the repository system at long timescales. For example, the flux from the container in the first 100 years or so may not influence the overall health impact of the repository in the distant future and hence would not necessarily be a useful indicator to consider.

HPA considers that some indicators other than dose can be usefully used to give a broader understanding of the performance of a disposal facility.

Question 9: **a) Are there any other safety indicators that could be usefully considered? b) If so, how might they be applied?**

6.7 Summary of proposals

The proposals are as follows.

- An annual risk constraint for natural processes and events of 10^{-5} per year using the ICRP detriment-adjusted risk coefficient. Repositories giving rise to greater risks would not be acceptable. Optimisation is also required to demonstrate that any risks below this level that arise from the repository are as low as reasonably achievable. If two or more disposal facilities exist on the same site under common management then the risk constraint will apply to the sum of the risks to a member of the exposed group if the exposure groups are the same and the exposure occurs at the same time.
- The annual risk constraint applies to detriment, using a risk coefficient of 0.06 per Sv for effective doses below 0.1 Sv.
- A lower guidance level of risk for natural processes and events of 10^{-6} per year, again using the ICRP detriment adjusted risk coefficient. If risks are below this level then the scope of the optimisation study can be restricted to the design of the repository.
- A dose guidance level of 20 mSv (total dose) for inadvertent human intrusion for near surface facilities for short-term exposures, ie of a duration less than a few weeks.
- An annual dose guidance level of 3 mSv per year for inadvertent human intrusion for near surface facilities for exposures lasting for greater than one year.
- No dose guidance level for inadvertent human intrusion for deep geological facilities but use of ‘stylised scenarios’ when undertaking assessments in order to explore the range of likely probabilities and consequences of intrusion and to demonstrate that the site has been optimised.
- The total probability of a person receiving a dose above 0.1 Sv in a year as a result of naturally occurring processes and events should not exceed 1 in 1 000 000 per year.

- Doses from build up of radon gas in buildings should not be included in the estimates of dose and risk above but should be compared with the dose from naturally occurring radionuclides and national standards for buildings.
- Uncertainties in the estimates of doses and risks should be discussed.
- Collective doses are to be used for option comparison purposes only.

The changes from previous advice are:

- Risk will be given in terms of detriment rather than fatal cancers and serious hereditary effects. Detriment is defined in the ICRP recommendations (ICRP, 2007) as the probability of attributable fatal cancer, the weighted probability of attributable non-fatal cancers, weighted probability of severe heritable effects and length of life lost if the harm occurs. However ICRP's previous recommendations (ICRP, 1991) gave a risk coefficient of fatal cancer and serious hereditary effects as 0.06 per Sv and the new ICRP recommendations give the detriment adjusted risk coefficient as 0.06 per Sv so the numerical value will not change.
- The previous advice did not distinguish between near surface and deep geological disposal facilities.
- The previous advice was framed in terms of risk only and hence applied a risk constraint to natural processes and events and to human intrusion. This advice considers dose criteria for human intrusion.

7 ASSESSMENT OF DOSES AND RISKS

The estimation of future radiation doses to people necessarily involves some degree of modelling of radionuclide transfer pathways from the repository, through the geosphere and into the biosphere. However, there are large uncertainties involved in biosphere modelling over timescales of thousands of years, especially with respect to the landscape and future behaviour of human populations, which cannot be predicted with any confidence for periods of more than a few decades. Over still longer timescales there will also be changes to the geosphere. Hence, the further into the future that the assessment is made, the more uncertain the estimates of doses and risks become. The following sections discuss changes in the geosphere and the biosphere (including human behaviour) over time and how these link to approaches to assessment of doses and risks.

It should be noted that any assessments of doses and risks to people should be regarded solely as estimates of potential impacts based on the documented assumptions. They can be seen as indicators of safety rather than predictors of safety. The half-lives of the radioactive material disposed to the facility will need to be considered as it may not be necessary to do calculations out to long time periods if sufficient decay has occurred due to short half-lives.

7.1 Operational phase

Assessments of doses to workers and doses to the public from any discharges during the operational phase should be performed in the same way as for any licensed nuclear facility. Further guidance on the assessment methodology for discharges is addressed in the Environment Agency's Principles document (Environment Agency et al, 2002b). This recommends that assessments of the radiological impact of discharges should consider pathways and exposed groups that are representative of the situation over the next five years (the time period until the next discharge review) and consider the build-up in the environment over 50 years. Uncertainty in the doses should also be addressed. In terms of assessing doses to members of the public from any releases occurring during this period, dose coefficients and habit data for three age groups should be calculated based on the representative person concept defined in ICRP's recent dose assessment recommendations (ICRP, 2006). HPA considers that the ‘representative person’ is essentially the same as the ‘representative member of a critical group’ discussed in the Principles document and that therefore this is just a change in terminology.

7.2 Changes in geosphere and biosphere and timeframes to be considered in post-closure safety case

Some radionuclides have half-lives of millions of years and hence assessments need to consider these very long timescales. As discussed in the BIOCLIM biosphere modelling report (Texier et al, 2004) looking into the future, global warming may cause onset of the next glaciation to be delayed, but it is expected that we will continue in glacial cycles with a period of 10 000y or so.

It is useful to divide the future into a series of different timeframes as the uncertainties associated with the dose or risk assessment increase with time and therefore the appropriate approach changes from a more quantitative one to a more qualitative one.

Assessments of the impact of the disposal of radioactive waste use the term ‘normal evolution’ to describe the set of natural processes that are almost certain to occur at the site. Typical assessments often use a constant current state as being the ‘normal evolution’ scenario together with a number of “what if” scenarios to span the range of possibilities eg, the possible effects of global warming over next few thousand years. Guidance on assessment methodologies for the post-closure phase has been developed by the IAEA BIOMASS and ISAM projects (IAEA, 2003; IAEA, 2004b).

7.2.1 Facility closure to end of active institutional control

The time period for active institutional control may vary depending on the type of facility and could be of the order of decades. For a small near surface facility, which is likely to contain low level waste (LLW), then the period specified for active control may be significantly less than for a deep geological facility. During the period of active institutional control the system of dose limitation should be applied as for an operational facility (see Section 7.1)

Examples of active institutional control are:

- monitoring;
- surveillance eg inspection of repository cover, drains leachate collection and monitoring systems and fences and warning signs prohibiting access to the site;
- corrective actions if required.

For the purposes of this document, the end of active institutional control is represented by the point at which there is no longer any on-site management; for a purpose built licensed facility this may, but does not necessarily, correspond to the time when the site is delicensed by the Nuclear Installations Inspectorate (NII). For a landfill style site this may be when the decision is made to cease routine maintenance and monitoring, several decades after closure. Even after the end of active institutional control, passive institutional controls may still be in place such as accessible records of the existence of the repository and land use control.

7.2.2 End of active institutional control – 10 000 years

During this time period, which essentially covers the period prior to the next glaciation, the biosphere may be expected to remain broadly comparable to present-day temperate conditions although there may be major local and regional changes over timescales of thousands of years (eg rivers or lakes drying up, coastal erosion and environmental effects associated with climatic change). Human behaviour is likely to change greatly over this time period, though it could be argued that physiological and hence dietary requirements may remain broadly similar. However, significant natural changes in the UK geosphere on this timescale are unlikely.

Obviously it is not actually possible to predict the location of the exact group of people that will be exposed to the highest doses in the future and hence some assumptions have to be made. HPA proposes that doses and risks are assessed for a hypothetical representative person in a reference biosphere. In line with the precautionary principle and the principle of protecting future generations to the standards we accept today, HPA proposes that the possible exposures are calculated in the following way. Firstly, for natural processes and events there will be a part of the biosphere where the concentrations resulting from the repository are greatest eg where any radioactivity that has migrated from the disposal site reaches the Earth’s surface. It is conservatively assumed that the hypothetical representative person inhabits this area at the time that the concentration at the surface is at its maximum. It is also assumed that this hypothetical representative person behaves in a similar way to present day people in that region, hence the characteristics of the hypothetical representative person and consequently the exposure pathways can be established by following the approach recommended by ICRP for determining the characteristics of the representative person (ICRP, 2006). This is essentially the same as previous NRPB advice, updated to bring it into line with the new ICRP terminology of the representative person. For inadvertent human intrusion, HPA recommends that it is conservatively assumed that intrusion could occur as soon as passive institutional control ceases but that other (later) times of intrusion are also considered to scope the range of possible results as discussed above in Section 5.4. Again the characteristics of the hypothetical representative person are based on present day characteristics.

It is recommended that a number of hypothetical representative person and scenarios are considered to ensure that a sufficient number of significant exposure pathways have been identified to provide adequate assurance of the protection of future communities. Depending on the type of facility being considered and the radioactivity being placed in the disposal facility, these scenarios and hypothetical representative person may include a farmer living in a temperate climate, a geotechnical worker examining drilling cores and a construction worker excavating a site. Although the biosphere can be assumed to remain broadly similar to the present day eg temperate, the effect of expected changes to the biosphere, such as climate variation leading to increased irrigation or coastal erosion and inundation, should also be addressed.

7.2.3 10 000 – 1 000 000 years

Repeated glacial cycling is expected to occur within this timeframe (Texier et al, 2004) and whilst it may be possible to make general predictions about environmental conditions the ranges of possible biosphere conditions and especially of human behaviour are too great to allow reliable modelling of the biosphere. Obviously, there is the possibility that glaciation will have eroded significant areas of the surface but there is also the possibility that, as a result of either such erosion or of technological developments, humans will no longer live anywhere near the disposal site. Therefore, in line with the principle of protecting future generations to the standards we accept today HPA proposes that calculations are performed to give an indication of the possible range of exposures using stylized ‘reference’ assumptions. This involves considering a few reference biospheres including the biosphere considered for the earlier timeframe. Since any calculated exposures can only provide an indication of the level of dose that could be received, HPA considers that the concept of the hypothetical representative person requires modification for this timeframe. Therefore HPA recommends that doses are calculated for exposures to a hypothetical representative person from a ‘reference community’. The reference community should normally comprise of ‘typical subsistence farmers’. They should not have extreme habits eg they should not be extreme consumers of particular foods. A small number of reference communities may be appropriate to reflect a range of conditions. In line with the precautionary principle, the reference community for natural events and processes is conservatively assumed to be located where the highest environmental concentrations are, at the surface of the biosphere. Inadvertent intrusion should also be considered in this time period, using present day characteristics to ensure protection of future generations to the same standard as current generations.

7.2.4 After 1 000 000 years

One million years is the approximate age of the human race. It is also the timescale over which stable geological formations can be expected to remain relatively unchanged. The scientific basis for dose and risk calculations beyond one million years is therefore highly questionable, and assessments beyond times of, at most, a few million years can only be interpreted in a qualitative manner. In other words, they can be used to provide information on, for example, when the peak flux to the environment may occur and whether it could be significantly higher than the peak flux that occurs before one million years. However, HPA considers that it is inappropriate to apply numerical dose or risk criteria in this timeframe. Obviously, it is possible to apply the same stylised ‘reference’ assumptions used for the previous time period but it should be remembered that any values of dose or risk estimated for this time period are highly speculative. Demonstration that doses or risks are as low as reasonably achievable (ALARA) in this time frame is limited to a discussion using qualitative arguments.

***Question 10:* Do you agree in general with the proposed approaches for assessing doses and risks?**

8 OTHER ISSUES

The recent UK Government waste management policy developments (Defra et al, 2006a; Defra et al, 2006b; Defra et al, 2007a) refer to the waste management hierarchy which describes the priorities when managing radioactive waste: namely reduce, reuse, recycle, dispose. HPA is supportive of this general approach: it is important to minimise the amount of radioactive waste generated from a practice. However, consideration of the relative importance of reuse, recycle or dispose options also needs to take into account the protection of human health in a broad sense in order to keep doses ALARA. Similarly, and in line with the precautionary principle, HPA considers that radioactive waste should be put into a safe form as soon as practicable.

Obviously, management options for some waste, particularly that containing long lived radionuclides, may consist of several stages. This is the case with intermediate and high level waste where CoRWM recommends a period of secure storage followed by disposal in deep geologic formations. HPA advises that consideration of the management options at the end of each phase should include all the options appropriate to the characteristics of the waste at that time. Specifically, if the radioactivity in the waste has decayed sufficiently to reclassify it as a different (lower category) type of waste then the appropriate options for that different category should be considered. This will ensure that doses are kept ALARA, economic and social factors being taken into account.

The previous advice from NRPB discussed the importance of the presentation of the results and the need for waste disposal safety assessments to be presented in as clear and comprehensible a form as possible. In particular, it is useful to refer to Table 1, taken from the previous advice, giving a perspective on the timescales that have to be considered. An important aspect in the assessment of the overall impact of a disposal facility is stakeholder involvement and hence the results of a radiological assessment should be understandable to them. In addition there are non-radiological protection objectives which will need to be considered in any assessment of the suitability of a disposal facility and these should also be discussed in a clear and transparent manner. Some of the other factors identified by CoRWM (CoRWM, 2006) as part of its assessment criteria were non-radiological health and environmental impacts, including short-term impacts such as transport and noise, security and socio-economic factors, ease of implementation, the burden to future generations, flexibility and cost.

Table 1 Timeframes considered in post-closure assessments

Years	Historical	Future	Nuclide half-life
100	Discovery of radioactivity	'Greenhouse' effects	
1,000	Norman conquest	Large ecological changes, *eg* lakes fill with weeds	
	Egyptian pyramids	Mineral and energy resources exhausted?	^{14}C
10,000	Discovery of agriculture		^{239}Pu
	Last glaciation of northern Europe	Next glaciation	
	Use of fire and tools by humans		
100,000	Emergence of the Neanderthal man	Time between major glaciations	^{99}Tc
1,000,000	Emergence of *Homo Sapiens*	Stable geological formations remain relatively unchanged	^{237}Np
	Evolutionary branching between humans and apes		
10,000,000		Spontaneous appearance of new families of species	^{129}I
100,000,000	Dinosaurs populated the earth	Large-scale movements of continents (thousands of kilometres)	

The UK Government will be responsible for outlining the process by which stakeholders are involved in deciding on the best approach for the disposal of solid radioactive waste. HPA believes that timely engagement with relevant stakeholders will provide substantial benefits and result in the optimisation, in a more broad sense, of the radiological impact of the final management option for radioactive waste.

The issue of monitoring of the repository, both during the operational and post-closure phases, was raised during CoRWM's consultation on the management options for intermediate and high level waste (CoRWM, 2005). HPA expects that the regulatory authorities will require monitoring of the disposal facility during operation and possibly for some time period following the closure of the site. The purpose of this monitoring would be to demonstrate that the disposal facility is operating as planned. It is difficult to specify the duration for which monitoring should continue as there may be no detectable levels of radionuclides in the environment for a long time if the repository operates as planned. For example, for a deep geological disposal facility, operating as planned, there will be no detectable levels of radioactivity in the biosphere or the geosphere around the facility until thousands of years after closure. HPA considers that the need or otherwise for any post-closure monitoring of a repository should be determined through stakeholder involvement and would be carried out primarily for reasons of public reassurance. It would also be reviewed regularly during the operational and active institutional control stages. It is important that any monitoring of the disposal facility does not compromise the integrity of the facility eg drilling of boreholes to monitor a disposal facility does not create a route for groundwater entry into the facility.

Question 11: **Do you have any other comments on the proposals in this document?**

9 QUESTIONS RAISED

Question 1: **HPA has categorised the exposure routes that should be assessed into three broad types: natural processes, natural events and inadvertent human intrusion. Are there other categories of exposure routes which HPA should consider?**

Question 2: **What measures of health impact(s) should HPA consider for assessing the radiological impact of repositories post-closure: dose, detriment-adjusted risk or fatal cancer risk?**

Question 3: **HPA has proposed a risk constraint of 1 in 100 000 per year for natural processes and events. Do you agree with this value? If not, why not? Should the risk constraint be set for a single facility or all disposal facilities affecting the same exposure group at the same time?**

Question 4: **Is the HPA proposal the best way to deal with prevention of doses giving deterministic health effects from natural events? If not, what would be a better approach?**

Question 5: **HPA is proposing dose based criteria for calculations of inadvertent human intrusion into near surface disposal facilities. HPA proposes a dose guidance level of 20 mSv is used for short-term exposures and an annual dose guidance level of 3 mSv per year for exposures lasting more than 5 years. What dose criterion do you think should apply to exposures that last more than a few weeks but less than 5 years: the 20 mSv total dose, the 3 mSv annual dose or another value?**

Question 6: **HPA is proposing different approaches for deep geological and near surface disposal facilities for inadvertent human intrusion. For deep geological facilities it is proposed that no dose guidance level is set but that 'stylised scenarios' are used to explore the likely consequences. Do you have any comments on this proposed approach?**

Question 7: **Is the concept of a lower guidance level useful? If so, do you agree that it should be set at 1 in 1 000 000 per year? If not, why not?**

Question 8: **Is collective dose a useful concept for assessing the disposal options for long-lived waste: a) for the first 500 years post-closure? b) for the very long term? If not, why not?**

Question 9: **a) Are there any other safety indicators that could be usefully considered? b) If so, how might they be applied?**

Question 10: **Do you agree in general with the proposed approaches for assessing doses and risks?**

Question 11: **Do you have any other comments on the proposals in this document?**

10 HOW TO SUBMIT YOUR VIEWS

HPA would prefer comments in electronic form. Please send your response to the questions (including your reasons for your comments), to arrive **no later than 3rd June 2008, to:**

By email:	SolidWasteDisposal@hpa.org.uk
By post:	Waste Management Group Health Protection Agency – Radiation Protection Division Chilton, Didcot OX11 0RQ

Deadline

The consultation period ends on 3rd June 2008

HPA may publish or otherwise make public the responses and comments it receives. If you do not wish your comments to be made public then you must clearly request that your response be treated confidentially. If you wish any non-confidential response to be unattributable, please let us know when you send it to us. Unattributable responses may also be included in any summary of comments received.

11 NEXT STEPS

The consultation will run until 3rd June 2008. Once this deadline has passed HPA will produce a document summarising the responses received and the Agency's views. HPA will then produce a document giving its advice on the radiological protection objectives for the land-based disposal of solid radioactive waste, to be published by the end of 2008.

12 GLOSSARY

Authorising departments

The Agency or Department responsible for granting an authorisation (permission) for disposal under Section 13 of the Radioactive Substances Act 1993. In England and Wales this responsibility lies with the Environment Agency, in Scotland with the Scottish Environment Protection Agency (SEPA), and in Northern Ireland with the Environment and Heritage Service, an agency within the Department of the Environment for Northern Ireland.

Deep geological disposal facility

Land based disposal facility whose depth, taken in the particular geological context, is sufficient to provide a very long delay – tens of thousands of years – before natural features, events and processes would be expected to allow any significant escape of radionuclides from the facility to the accessible environment. In this context, “deep” can imply horizontal instead of, or as well as, vertical distance as, for example, in the case of a disposal facility sited deep within a mountain.

Design target

Renamed ‘lower guidance level’ in this document. If risks from natural events and processes are estimated to be below the lower guidance level (design target) then optimisation can be limited to the design of the facility. The lower guidance level is set at a low level of risk commonly considered acceptable. A facility that is estimated to give risks above the lower guidance level could be acceptable if the facility concept, design and location are shown to be the overall optimum option, taking into account economic and social factors.

Detriment

Detriment (specifically radiation detriment) is a concept used to quantify the harmful health effects of radiation exposure in different parts of the body. It is defined by ICRP as a function of several factors, including incidence of radiation-related cancer or heritable defects, lethality of these conditions, quality of life, and years of life lost due to these conditions.

Detriment-adjusted risk

The probability of the occurrence of a stochastic effect, modified to allow for the different components of the detriment in order to express the severity of the consequence(s).

Disposal

In the context of this document, disposal is the emplacement of waste in a land disposal facility without intent to retrieve it at a later time; retrieval may be possible but, if intended, the appropriate term is storage.

Dose constraint

A prospective and source related restriction on the individual dose from a source, which provides a basic level of protection for the most highly exposed individuals from a source and serves as an upper bound on the dose in optimisation of protection for that source. For occupational exposures, the dose constraint is a value of individual dose used to limit the range of options considered in the process of optimisation. For public exposure, the dose constraint is an upper bound on the annual doses that members of the public should receive from the planned operation of any controlled source. Thus the dose constraint places a restriction on the annual dose to an individual from a particular source in order to ensure that when aggregated with doses from all sources, excluding natural background and medical procedures, the dose limit is not exceeded. The Government has set a maximum dose constraint value of 0.3 mSv y^{-1} when determining applications for discharge authorisations from a single new source, and a dose constraint value of 0.5 mSv y^{-1} for a complete site (which may include several sources with more than one operator).

Dose limit

The value of the effective dose or the equivalent dose to individuals from planned exposure situations that shall not be exceeded. For the purposes of discharge authorisations, the UK has (since 1986) applied a dose limit of 1 mSv y^{-1} to members of the public from all man-made sources of radioactivity (other than from medical applications).

Effective dose

The tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body. This takes account of the relative risks associated with exposure of different organs. It is measured in Sievert (Sv). The committed effective dose is the effective dose that will be received by the person over their lifetime as a result of radionuclides taken into the body e.g. by ingestion or inhalation.

Emergency exposure situations

Unexpected situations that occur during the operation of a practice, requiring urgent action. Emergency exposure situations may arise from practices.

Equivalent dose

The radiation-weighted dose in a tissue or organ. This takes account of the different amounts of damage caused by different types of radiation eg alpha particles, gamma radiation. It is measured in Sievert (Sv).

Existing exposure situations

Situations that already exist when a decision on control has to be taken, including natural background radiation and residues from past practices that were operated outside the Commission's recommendations.

Guidance level

A level of dose that can be exceeded only if the facility concept, design and location giving rise to the dose or risk is shown to be the overall optimum option, taking into account economic and social factors. If doses are estimated to be below the guidance level then optimisation can be limited to the design of the facility.

Guidance on requirements for authorisation (GRA)

A document produced by the Authorising departments giving the standards that they will use to judge an application for authorisation for disposal of radioactive waste. The current version of the document was published in 1996 and is currently being updated.

Inadvertent human intrusion

Accidental intrusion into a disposal facility without prior knowledge of the presence of the facility or accidental intrusion, without prior knowledge, into an area adjacent to the facility in such a way that it degrades the environmental safety performance of the facility.

Intervention

Any action intended to reduce or avert exposure or the likelihood of exposure to sources that are not part of a controlled practice or that are out of control as a consequence of an accident.

Justification

The process of determining whether either (1) a planned activity involving radiation is, overall, beneficial, i.e. whether the benefits to individuals and to society from introducing or continuing the activity outweigh the harm (including radiation detriment) resulting from the activity; or (2) a proposed remedial action in an emergency or existing exposure situation is likely, overall, to be beneficial, i.e. whether the benefits to individuals and to society (including the reduction in radiation detriment) from introducing or continuing the remedial action outweigh its cost and any harm or damage it causes.

Lower guidance level

Formerly called a design target. If risks from natural events and processes are estimated to be below the lower guidance level (design target) then optimisation can be limited to the design of the facility. The lower guidance level is set at a low level of risk commonly considered acceptable. A facility that is estimated to give risks above the lower guidance level could be acceptable if the facility concept, design and location are shown to be the overall optimum option, taking into account economic and social factors.

Natural events

Events that occur naturally, have a probability of happening, a specific starting time and a relatively short duration. Examples are flooding and seismic events.

Natural processes

Naturally occurring processes that have gradual, continuous interactions with the disposal facility. Examples are leaching of the radioactive waste and subsequent migration of radionuclides in the groundwater.

Near-surface disposal facility

Land based disposal facility that is located directly at the surface of the ground, or at depths down to several tens of meters below the surface. For facilities that are constructed at depth they may also be located such that although accessed from land the facility would be under the seabed. Such facilities might be constructed with the intent that they will be covered by clean material to a specified/suitable depth at closure or, in the case of deeper facilities, they might be excavated caverns within the existing rock mass. Additionally it is possible that use of existing structures, that are suitably located and for which a safety case can be made, may be proposed.

Normal evolution

The expected future state of the disposal facility and the environment.

Normal exposures

Exposure that is expected to occur under the normal operating conditions of a facility or activity, including possible minor mishaps that can be kept under control, i.e. during normal operation and anticipated operational occurrences.

Operational phase

The period during which a disposal facility is receiving waste and is being sealed before closure.

Optimisation of protection (and safety)

The process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, as low as reasonably achievable, economic and societal factors being taken into account.

Per-caput

The average level for a person.

Phased geological disposal option

The phased geological disposal option of the Government's Committee on Radioactive Waste Management (CoRWM) involves the incorporation of design features that would enable a repository to stay open and function as a storage facility for several hundred years – though it could be sealed much sooner, even vault by vault as each is filled.

Planned exposure situations

Everyday situations involving the planned operation of sources including decommissioning, disposal of radioactive waste and rehabilitation of the previously occupied land. Practices in operation are planned exposure situations.

Post-closure phase

The period after a disposal facility has been closed. This includes the active institutional control phase, the passive institutional control phase and the subsequent uncontrolled phase.

Potential exposure

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

Practice

Any human activity that introduces additional sources of exposure or additional exposure pathways, or extends exposure to additional people, or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed. Radioactive waste is generated as a result of practices and the management of this waste is therefore only one part of the overall practice.

Prolonged exposure

Exposure that continues at broadly the same level for periods of the order of decades or longer.

Reference level

In emergency or existing controllable exposure situations, this represents the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposures to occur, and below which optimisation of protection should be implemented.

Risk

The probability of harm, e.g. cancer, in a year. It takes into account the probability of receiving a dose in a year and the probability that the dose received will give rise to harm.

Risk constraint

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

Risk target

A concept defined by the Authorising agencies in the GRA. It is a level of radiological risk from a single disposal facility which provides a numerical standard for assessing the long-term performance of the facility. The numerical value of the risk target is one in a million.

Site

For a disposal facility, the piece of land where the facility is, or is intended to be, located. In the context of this document a site may contain more than one disposal facility under common management and is therefore analogous to the ICRP definition of a source.

Source

Defined by ICRP as an entity for which radiological protection can be optimised as an integral whole, such as the x-ray equipment in a hospital, or the releases of radioactive materials from an installation. Sources of radiation, such as radiation generators and sealed radioactive materials, and, more generally, the cause of exposure to radiation or to radionuclides. A source may be comprised of a number of facilities under common management.

Subsidence

The gradual sinking or settling of the ground surface through compaction. Sudden events may also occur due to collapse of underground caverns.

Uplift

The gradual rising of the ground surface that arises in the warmer period following a period of glaciation. The melting of the ice means that the weight of the ice is no longer pressing down onto the ground and therefore it slowly becomes less compacted.

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