ICRP GUIDANCE ON RADIOACTIVE WASTE DISPOSAL

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Abstract. The International Commission on Radiological Protection (ICRP) issued recommendations for a system of radiological protection in 1991 as the 1990 Recommendations. Guidance on the application of these recommendations in the general area of waste disposal was issued in 1997 as Publication 77 and guidance specific to disposal of solid long-lived radioactive waste was issued as Publication 81. This paper summarises ICRP guidance in radiological protection requirements for waste disposal concentrating on the ones of relevance to the geological disposal of solid radioactive waste. Suggestions are made for areas where further work is required to apply the ICRP guidance.

1. INTRODUCTION

The International Commission on Radiological Protection (ICRP) issued its latest general recommendations for protection against ionising radiation in 1991 as the '1990 Recommendations' [1]. In 1997, ICRP elaborated on these general recommendations in the context of radioactive waste issuing its 'Radiological protection policy for the disposal of radioactive waste' [2]. This policy addressed all types of radioactive waste, short-lived, long-lived, solids, liquids and gases. It was followed, in 2000, by Publication 81 which developed recommendations specifically for the disposal of long-lived solid radioactive waste [3].

This paper describes the key aspects of these ICRP recommendations focussing particularly on the ones of relevance to geological disposal of long-lived waste. Emphasis is placed on the criteria and principles that would apply to new purpose built facilities

2. THE 1990 RECOMMENDATIONS

These provide ICRP's fundamental recommendations for protection of people from ionising radiation. They are intended for general application, covering the full range of circumstances of exposure, only those of relevance to radioactive waste disposal are addressed here.

The 1990 Recommendations distinguish between two types of exposure situations: practices and interventions. Practices are deliberate human activities which, as a by-product, result in increased exposure of individuals or populations and, in principle, can be designed and operated to meet radiological protection requirements that are specified in advance. Interventions are human activities intended to decrease overall exposure and apply in situations in which the source of exposure is already present when decisions on protective actions are to be taken. The basic principles of radiological protection are used to establish the levels of control of exposure in both practices and interventions but are applied in different ways.

This paper is largely concerned with the principles of protection for practices, which are in summary:

Justification	– overall a practice should do more good than harm
Optimisation	– the margin of good over harm should be maximised
Dose and risk limitation	– an adequate standard of protection should be provided for the most exposed individuals

Additionally, in applying the principle of protection for optimisation a constraint should be placed on the maximum dose or risk incurred by individuals. This constraint should correspond to a value less than the dose limit for members of the public. ICRP, however, in Publication 60 did not recommend a value for the constraint. The constraint is applied prospectively; options implying doses or risks higher than the constraint should be rejected.

The basic tenet underpinning these principles is the linear-no threshold hypothesis.

In many situations it is virtually certain that exposures will occur and their magnitude will be predictable, albeit with some degree of uncertainty. These are referred to as 'normal exposures'. Conversely, there may be circumstances where exposures do not occur as planned or where there is a potential for exposure, but no certainty that it will occur. ICRP calls such exposures 'potential exposures' recommending that they should be taken into account when considering the need for protective actions.

Exposures arising in the future following the disposal of solid radioactive waste will depend on events and processes that have probabilities associated with them and, as such, would be potential exposures.

3. PUBLICATION 77: RADIOLOGICAL PROTECTION POLICY FOR THE DISPOSAL OF RADIOACTIVE WASTE

This publication extended and developed the 1990 Recommendations for specific application to the disposal of all types of radioactive waste, including effluents as well as solids. It was produced in response to a perceived need to clarify the application of the 1990 Recommendations in this area. Particular issues included application of the justification and optimisation principles to waste disposal in circumstances where doses to individuals and populations may be projected to be received over extended periods of time into the future and with increasing associated uncertainties. The use of the quantity collective dose in this context was a particular issue as was the type of criteria that should be applied in establishing whether individuals in future populations were being afforded an adequate degree of protection.

In general, ICRP considers that the main radiological protection issue in waste disposal is public exposure. This should be controlled through the process of constrained optimisation. A value for the dose constraint for members of the public of no more than about 0.3 mSv in a year is suggested to be appropriate. Use of this process, it is suggested by ICRP, would obviate the direct use of dose limits for members of the public and as such, in this context, they should progressively fall out of use.

ICRP clarified application of the principles of justification and optimisation. In the case of justification, as waste management and disposal operations are an integral part of the practice generating the waste, it is wrong to regard them as a free standing practice that needs its own justification. It follows that consideration should be given to such operations in the process of deciding whether the practice generating the waste is justified or not. In the context of optimisation, ICRP considered that this principle had become too closely linked to quantitative techniques such as differential cost benefit analysis. Whereas, ICRP's policy is more judgmental being summarised, in essence, by the following statement taken from Publication 55 [4], "Have I done all that I reasonably can to reduce these radiation doses?"

The use of the quantity collective dose is linked to the application of the principles of justification and optimisation being a broad indicator of detriment to the exposed population. Collective dose is an aggregated quantity and problems arise by use of collective doses from very small doses to large populations and from doses occurring over very long times. In the case of very small doses, ICRP does not recommend that the component of collective dose due to small individual doses should be ignored solely because the individual doses are small. Where possible, however, it would provide more information for decision-making purposes to separately identify that component of the total collective dose which is delivered at very small individual doses; decision-makers could, for example, place lower weight in the decision-making process on this component versus the components of collective doses that are delivered at larger individual doses. The weight attached to collective doses delivered over long time periods into the future was also addressed by ICRP. Uncertainty is the main problem. Both the magnitude of the individual doses and the size of the exposed population become increasingly uncertain as the time increases. There is also the issue that current judgements about the relationship between dose and health effects (or detriment) may not be valid for future generations. In the light of such arguments, ICRP suggests that forecasts of collective doses over periods longer than several thousand years and forecasts of health detriment over periods longer than several hundreds of years 'should be examined critically'.

Overall, ICRP argues that when collective doses are being considered in decisions on waste management options, it is more informative to present the doses in blocks of individual dose and time intervals.

On the question of judging the significance of possible harm to future generations from decisions taken today, ICRP investigated a number of quantities including individual doses and risks, and collective doses. The conclusion was that the appropriate quantities to use are the calculated annual individual doses and risks in the relevant critical groups.

ICRP, in Publication 77, makes important observations about the practical implications of considering potential exposure in waste management decisions. The possibility of potential exposure distinguishes between the two waste disposal strategies 'Dilute and Disperse' and 'Concentrate and Retain'. Direct discharge of radioactive waste to the environment, the dilute and disperse option gives rise to more or less immediate critical group doses whose magnitude can be assessed reasonably reliably. Potential exposure is usually not an issue. The retention strategy usually eliminates or significantly reduces public exposures at least in the short to medium term. It can appear, therefore, the more protective of the two strategies. Consideration of potential exposure may influence this view as events with probabilities associated with them could lead to significant exposures. For example, there is the possibility, which is discussed in more detail later, of inadvertent human intrusion into the waste. ICRP recommends that waste disposal policies should take account of potential and normal exposures. Furthermore, the dispersion of radioactive waste should not automatically be regarded as a less suitable option than retention. For solid waste, however, disposal in a more or less undiluted form is often the only viable option.

4. PUBLICATION 81: RADIOLOGICAL PROTECTION RECOMMENDATIONS AS APPLIED TO THE DISPOSAL OF LONG-LIVED SOLID RADIOACTIVE WASTE

This further develops the 1990 Recommendations [1] and the policy for the disposal of radioactive waste [2] specifically in the context of the disposal of solid long-lived radioactive waste. The disposal options considered are surface or near surface disposal and geological disposal. All types of solid long-lived radioactive waste are covered in Publication 81 including solid high level waste and large volume low level waste. Issues addressed include the radiological protection criteria that should be applied in establishing whether future populations are being adequately protected, and guidance on how to apply the optimisation principle in waste disposal. Particular consideration is given to evaluating the significance of exposures arising as a result of direct inadvertent human intrusion into a waste disposal facility. This publication also extends and develops proposals in an earlier ICRP publication, ICRP 46 [5], which also addressed disposal of solid radioactive waste.

ICRP considers, in Publication 81, that the main protection issues concern exposure of members of the public that may or may not occur in the future. Furthermore, individuals and populations in the future should be afforded at least the same level of protection from the action of disposing of radioactive waste today as is the current generation. This implies the use of the current dose and risk criteria derived from considering associated health detriment. Therefore, in principle, protection of future generations should be achieved by applying these dose and risk criteria to the estimated future doses and risks in appropriately defined critical groups. These criteria are dose limits and dose and risk constraints. However, as it is impossible to know in advance what the total dose to future individuals will be from practices, the appropriate criteria are the constraints: constrained optimisation is the central approach to evaluating the radiological acceptability of a waste disposal system.

Knowledge of the disposal facility may be lost in the future and, consequently, it cannot be assumed that any mitigation measures would be carried out to reduce doses should these reach unacceptable levels. An effective disposal facility will, however, retain the waste during the period of greatest potential hazard with only residual radionuclides entering man's environment in the distant future. In this future time period, two broad categories of exposure situation are distinguished: natural processes and human intrusion. The term human intrusion covers inadvertent human actions affecting repository integrity and potentially having radiological consequences. It is more likely to occur after knowledge of the repository has been lost, *ie*, in the far future. The term, natural processes, includes all the processes that lead to the exposure of individuals other than human intrusion. Application of radiological protection criteria to these two categories of exposure situations is different.

Natural Processes. These processes include the foreseen gradual degradation of the repository together with other, less likely, natural processes that may disrupt the performance of the repository. Therefore the objective of protecting the public in such circumstances would have to consider both the probability of occurrence and the magnitude of the corresponding exposures. This can be achieved by either aggregating the probabilities and corresponding doses (or rather the risk equivalent of the dose) in an overall evaluation of risk or by separate consideration of the dose and associated likelihood of occurrence of the exposure in a disaggregated approach. The key criterion is the dose constraint for members of the public. An upper numerical value of 0.3 mSv y^{-1} has been recommended by ICRP (see section 3); this corresponds to a risk constraint of the order of 10^{-5} per year. In the aggregated approach, the total risk to a representative critical group is compared with the risk constraint. This is conceptually satisfying but requires a comprehensive evaluation of all relevant exposure situations and their associated probabilities of occurrence; a process that can be difficult to achieve in a transparent and convincing manner. In the disaggregated approach, likely or representative release scenarios are identified and the calculated doses from these scenarios are compared with the dose constraint. The radiological significance of other, less likely, scenarios can be evaluated from a separate consideration of the resultant doses and their probabilities of occurrence. ICRP considers that although a similar level of protection can be achieved by these approaches, more information can be obtained for decision-making purposes from the disaggregated approach.

All of these approaches require assessments of doses or risks to critical groups. Due to the long timescales under consideration, the habits and characteristics of the critical group as well as those of the environment in which it is located can only be assumed. Thus, the critical group is hypothetical. It should be chosen on the basis of reasonably plausible assumptions taking account of current lifestyles and site or region specific information. In many cases different exposure scenarios with their associated critical groups will have different probabilities of occurrence and therefore the highest dose may not correspond to the highest risk. Because of this, ICRP suggests that it is important to clearly present the different exposure scenarios and their associated probabilities of occurrence in the decision-making process.

The long timescales under consideration impact on the importance attached to the assessed doses and risks. These estimates, according to ICRP, should not be regarded as measures of health detriment beyond times of around several hundreds of years into the future. In the case of longer time periods, they represent indicators of the protection afforded by the disposal system.

Human Intrusion. The possibility of elevated exposures from human intrusion is an inescapable consequence of the decision to concentrate waste in a discrete disposal facility. An intrusion event could result in radioactive material being brought to the surface resulting in the exposure of nearby populations to significant radiation doses. How should such events be taken into account in evaluating the radiological acceptability as a waste disposal option?

In principle, a risk based approach, considering both the probability and consequences of human intrusion, could be used to evaluate the radiological significance of human intrusion. ICRP, however, cautions against this approach as there is no scientific basis for predicting the nature or probability of the corresponding future human actions. Instead ICRP suggests that it is the radiological consequences of intrusion that should be considered. It is emphasised, however, that these consequences should not be compared with the dose constraint of 0.3 mSv per year for members of the public; this constraint applies during the process of optimisation of protection and, by definition, intrusion will have by-passed all of the barriers which were considered during the optimisation process. So, what should the consequences be compared with? ICRP considers that in circumstances where human intrusion could lead to doses to those living around the site sufficiently high that intervention on current criteria would almost always be justified, reasonable efforts should be made to reduce the probability of intrusion or to limit its consequences. General criteria for intervention in the case of long-term exposures have been established in ICRP 82 [6] and ICRP suggests that these could be used to evaluate the significance of human intrusion. Briefly, these criteria are that an existing annual dose of 10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable, whereas at 100 mSv per year and above, intervention is considered to be almost always justifiable. The term existing annual dose refers to the sum of the existing and persisting annual doses to individuals at a given location. The exposure that may occur from a repository is one component of this. The doses should be assessed using plausible stylised exposure scenarios representing human intrusion events.

This guidance from ICRP addresses the exposures to individuals in local population groups but there is the issue of the exposure of the intruder. This is not directly addressed by ICRP.

Technical and Managerial Aspects. ICRP considers that the technical and managerial principles developed generally for potential exposure situations in ICRP 64 [7] should be applied during disposal system development to enhance confidence in radiation safety. These principles should be applied to disposal systems in a manner consistent with the inherent level of hazard of the waste as well as with the level of residual uncertainty identified in the assessment.

One of the key principles is the concept of defence in depth which provides for successive passive safety measures which enhance confidence that the disposal system is robust and has an adequate safety margin. In addition to the technical principles, an essential managerial principle for all individuals and organisations involved in the repository development process is to establish a consistent and pervading approach to safety which governs their actions.

Compliance with Radiological Criteria. This is a difficult topic because of the inherent uncertainties in our estimates of radiological impacts on future generations. For this reason, demonstration that radiological protection criteria will be met in the future is not as simple as a straightforward comparison of estimated doses and risks with the appropriate constraints. Judgement may be required. ICRP points out that the dose and risk constraints should be considered as reference values for time periods beyond several hundreds of years into the future, and additional arguments should be brought to bear when judging compliance. A decision on the acceptability of a disposal system should be based on reasonable assurance rather than on an absolute demonstration of compliance with numerical criteria.

Overall, ICRP's view on compliance is that provided that the appropriate constraint for natural processes has been appropriately satisfied, that reasonable measures have been taken to reduce the probability of human intrusion and that sound engineering, technical and managerial principles have been followed, the radiological protection requirements can be considered to be satisfied.

5. CONCLUSIONS

From its general Recommendations issued in Publication 60, ICRP has developed a framework for evaluating the radiological acceptability of options for the disposal of all types of radioactive waste. The central process is one of constrained optimisation. To be used, this framework requires elaboration in a number of areas by the appropriate national or international organisations. These areas include:

— Characterisation of critical groups and the associated biospheres for use in estimating doses or risks from *natural processes.*
— Development of stylised human intrusion scenarios for evaluating the significance of *human intrusion.*

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