HUMAN INTRUSION: NEW IDEAS?

J.R. Cooper
National Radiological Protection Board,
Chilton, Didcot, Oxon, United Kingdom

Abstract. Inadvertent human intrusion has been an issue for the disposal of solid radioactive waste for many years. This paper discusses proposals for an approach for evaluating the radiological significance of human intrusion as put forward by ICRP with contribution from work at IAEA. The approach focuses on the consequences of the intrusion. Protective actions could, however, include steps to reduce the probability of human intrusion as well as the consequences.

1. INTRODUCTION

There are a number of different definitions of 'Human Intrusion' but they are all largely along the following lines:

Unintentional human actions that affect repository integrity and potentially have radiological consequences.

Intentional human actions of this sort are the responsibility of the intruder and are conventionally specifically excluded from consideration.

Human intrusion is an issue for disposal options that attempt to contain waste for extended periods of time. The issue arises from two aspects of waste disposal, one of which is a physical reality, the other of which is to some extent a matter for conjecture. The physical reality is that there are some types of waste that contain radionuclides with half-lives that are so long that the waste remains a radiological hazard for thousands of years into the future. Direct human controls over a repository containing these types of waste, which would serve to prevent human intrusion, cannot be assumed to last for such extended time periods, although when and how these controls might fail is a matter for conjecture.

Against this background, the possibility of human intrusion occurring when knowledge of the repository has been lost, cannot be ruled out. Thus, the questions that have to be answered in evaluating the radiological acceptability of a disposal option for radioactive waste are:

— What radiological criteria should be used in evaluating the significance of human intrusion?
— How should compliance with the criteria be evaluated?

The answer to the second question depends to some extent on the answer to the first.

These two questions are addressed in turn.

2. RADIOLOGICAL CRITERIA FOR HUMAN INTRUSION

Two features of human intrusion are important in the following discussion:

(a) The intrusion occurs at times after all knowledge of the repository has been lost.

— Direct control over the repository must have ended, either intentionally or accidentally, or the intrusion presumably could not occur.

— The fact that all knowledge has been lost means that it cannot be assumed that mitigating actions will be taken in the event of intrusion.

(b) At the times when human intrusion can take place, by definition, the only protective barriers between the waste and the human environment will be passive ones.

In the terminology of the International Commission on Radiological Protection (ICRP) human intrusion is a potential exposure situation: there is a potential for exposure but no certainty that it will occur [1]. So, the first question to be asked is whether human intrusion can be considered within a risk based framework. Generally, this type of approach has been used in some countries at least, in assessing the acceptability of waste management options. In this approach the probability of occurrence of a particular intrusion event is combined with the radiological risk to health of the affected individual to produce an estimate of risk. Thus intrusion events with high consequences could be acceptable provided the estimated probability of occurrence is sufficiently low. In most instances where this approach has been adopted, the annual probability of occurrence has been used to provide an estimate of annual risk which can then be compared to a criterion framed in these terms. This approach is conceptually satisfying but has been criticised on the grounds that the estimated probabilities of occurrence are arbitrary. They, nevertheless, may have a considerable impact on the final answer. Specifically, ICRP in publication 81, states that 'since no scientific basis exists for predicting the nature or probability of future human actions, it is not appropriate to include the probabilities of such events in a quantitative performance assessment that is to be compared with dose or risk constraints' [2]. This statement echoes a similar one made by the National Research Council of Sciences of the United States in its 'Technical Bases for Yucca Mountain Standards' [3]. This leads to the idea, espoused by ICRP, that attention should focus on the magnitude of the exposures that could occur if the intrusion happened.

Following the above arguments, the next question is what dose criterion should be applied in assessing the acceptability of the exposures arising from human intrusion? A starting point is the current dose limits and constraints. It does not, however, appear reasonable to apply the dose limits and constraints that are used today in the control of operating practices, the performance of which can be verified and corrected if necessary, in circumstances where no such verification or correction is possible. Similar concerns are expressed by ICRP in connection with the dose constraint for members of the public as used in the optimisation of protection: 'This constraint is not applicable in evaluating the significance of human intrusion because, by definition, intrusion will have by-passed the barriers that were considered in the optimisation of protection for the disposal facility' [2]. Instead, ICRP points to criteria for intervention: 'The Commission 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 human intrusion or to limit its consequences'. In situations where these doses occur for prolonged periods of time, ICRP suggests that the criteria it has developed in Publication 82 for intervention in prolonged exposure situations should be applied [4]. These criteria are that an existing annual dose of around 10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable and, conversely, an existing annual dose of around 100 mSv may be used as a generic reference level above which intervention should be considered almost always justifiable. The term 'existing annual dose' means the existing and persisting annual doses incurred by individuals at a given location. The radiological criteria for intervention were derived in Publication 82 from considerations of the variations in natural background and, in the case of the upper criterion, from considerations of the magnitude of prolonged doses that could give rise to deterministic effects. The chosen upper value was selected to be below a level where such effects might occur but where the risk of stochastic effects was approaching unacceptable levels if incurred on a year by year basis.

Such proposals for evaluating the acceptability of the doses arising from human intrusion can be criticised on the basis that intervention criteria are being applied to control a practice. This is not a valid criticism. The use of such criteria is appropriate because the source is, by definition, no longer under direct control when intrusion occurs. Similarly it could be argued that the same criteria, *ie*, the generic reference levels, should be applied in judging the acceptability of all other exposures arising in the future from a waste disposal facility. These other exposures are referred to under the term 'natural processes' (see [5]) and include exposures arising from the normal degradation of the waste followed by migration of radionuclides to the biosphere. It is, however, appropriate to use the constraint in this situation because the passive barriers put in place to restrict exposures from natural processes should be expected to perform adequately, albeit with some uncertainty, over the time period of concern.

The advice from ICRP on the acceptability of doses from human intrusion applies to individuals *living around the disposal site*. This raises the question of the intruder. What criteria, if any, should apply to him or her? If there are circumstances where the exposure is chronic, say occurring over periods of several years at a more or less constant rate, the generic reference levels could be used. Exposure of the intruder could, however, be acute and is perhaps likely to be so. For consistency with the upper generic reference level for prolonged exposure it is suggested in this paper that a corresponding level for acute exposure of an intruder should be set at a value where deterministic effects are unlikely. For whole body exposure this would correspond to a dose of around 500 mSv [6].

3. EVALUATING THE CONSEQUENCES OF INTRUSION

Having established the criteria for assessing the radiological consequences of intrusion it is necessary to decide on how those consequences are going to be estimated. From the above discussion it is clear that doses to the intruder need to be estimated together with the annual doses to individuals who receive prolonged elevated exposures as a result of the intrusion.

Given the potentially long timescales over which intrusion could occur and the fact that there is no scientific basis for predicting the nature of future human actions, the consequences of intrusion should be evaluated using plausible stylised intrusion scenarios. Such an approach is suggested by ICRP [2]. The scenarios should be chosen to be reasonably conservative, but not unduly so. If the scenarios are too conservative there is the possibility that the results from the calculations could distort the decision-making process by implying the need for more protective actions than may otherwise be deemed necessary.

A few scenarios should be sufficient to represent the range of possible intrusion scenarios. These scenarios would include:

(i) Direct access to waste from a geological repository. This type of situation will probably give rise to high acute exposure as the waste involved are likely to be the more highly active ones. The primary example of this type of scenario is the exploratory driller/technician who handles a core obtained from inadvertent exploratory drilling through a high level waste repository.

(ii) Direct access to a surface/near surface repository. Relatively low-level waste are likely to be involved and the exposures could be prolonged. Examples include disturbance of waste and its redistribution over the surface by building operations followed by exposure of the occupants.

(iii) Indirect exposure to radionuclides leaking from a repository whose barriers have been degraded by intrusion. These exposures are likely to be prolonged. Examples include exploratory drilling near a geological repository and thus providing a 'short circuit' to the surface.

In the case of some disposal options, in particular those involving disposal in salt formations, specific intrusion scenarios may need to be developed. For disposal in salt, the development of such scenarios should take into account the possibility of various forms of mining including solution mining. Further suggestions for intrusion scenarios are given in the fourth report of the working group on principles and criteria for radioactive waste disposal [7]. The BIOMASS programme is also developing guidance in this area.

4. APPLICATION

The primary radiological protection procedure applicable to waste disposal is optimisation of protection (see [5]). So, having estimated intrusion doses using the procedures outlined in section 3 and having compared the results with the criteria described in section 2, the question is: how is the outcome used in optimisation of protection? In answering this question it is useful to consider some example situations. First it is important to reiterate a point made earlier which is that even if the upper generic reference levels (see section 2) are exceeded the radiological protection requirement is that *reasonable* efforts should be made to reduce the probability of intrusion or to limit its consequences.

The first example is heat generating high level waste. It is possible to receive high doses, possibly leading to deterministic effects, in the time period up to 1000 years post disposal (intrusion scenario (i), section 3). Similarly any situation that leads to dispersion of the waste on the surface is likely to lead to doses in excess of 100 mSv per year (intrusion scenario (ii) or (iii), section 3). Thus, reasonable efforts should be made to reduce the probability or consequences of intrusion. As the consequences of intrusion are linked to the concentration of radionuclides in the waste, one possibility is to dilute the waste prior to disposal. The volumes that would be involved and the practical aspects of dilution, particularly for spent fuel, mean that this is not a viable option. This leaves reducing the probability of intrusion, which can be done by siting the repository at depth and in an area where the likelihood of human activities such as exploratory drilling is considered to be relatively low. It has to be remembered that there is nothing that can guarantee to prevent this type of intrusion.

The second example is low level waste. A particularly difficult case is waste containing long-lived natural radionuclides. If this waste is placed in near surface facilities, there is the possibility of human intrusion in the form of dwellings being constructed on top of the repository leading to disturbance or removal of some of the cover. Exposures could then arise to the occupants of the dwellings from, for example, radon if the waste contained radium-226. If the corresponding doses were estimated to be in the region where intervention might be justified on the basis of current criteria, the evaluation of what reasonable steps could be taken to reduce probabilities or consequences would have to take account of the volumes of waste involved. The optimum option may be near surface disposal.

In overall terms, the possible actions to reduce the probability of intrusion include increased depth of disposal, siting of the repository away from known natural resources, use of markers to alert a possible intruder to the presence of a man-made structure, and the maintenance of records and of other passive institutional controls that would help to preserve knowledge of the repository. Conventionally active institutional controls are only assumed to continue for a few hundreds of years into the future. ICRP, however, considers that there is no particular reason why institutional controls may not continue for extended periods of time and, therefore, may make a significant contribution to the overall radiological safety of shallow facilities in particular. ICRP also suggests that for surface or near surface disposal of uranium mill tailings, these controls may be relied on for long periods of time in situations where, if the controls fail, consequences will be generally lower than those associated with other long-lived radioactive waste.

It is perhaps more difficult to reduce the consequences of intrusion. For most intrusion scenarios, the consequences of intrusion will depend upon the concentration of radionuclides in the waste. Therefore, one way of reducing consequences is to dilute the waste. This would however increase the volume of waste to be disposed of and as a result might compromise the performance of the repository in other respects. Other ways of reducing consequences include eliminating areas in the repository that have significantly higher than average radionuclide concentrations-hot spots. The radiological implications of scenarios where engineered barriers have been degraded, such as scenario (iii) in section 3, could be reduced by siting the repository in an area with inherently good containment such that dependency on engineered barriers, which could be penetrated by intrusion, is reduced.

5. CONCLUSIONS

Guidance from ICRP and work done within the IAEA has led to a framework for evaluating the radiological significance of human intrusion. The approach focuses on the consequences of the intrusion. Protective action could, however, include steps to reduce the probability of intrusion as well as reducing the consequences.

REFERENCES

[1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1990 Recommendations of the ICRP, Publication 60, Annals of the ICRP Vol. 21 Nos. 1–3, Pergamon Press, Oxford and New York (1992).

[2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste, Publication 81, Annals of the ICRP Vol. 28 No. 4, Pergamon Press, Oxford and New York (1998).

[3] NATIONAL RESEARCH COUNCIL, Technical Bases for Yucca Mountain Standards, National Academy Press, Washington DC (1995).

[4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Protection of the Public in Situations of Prolonged Radiation Exposure, Publication 82, Annals of the ICRP Vol. 29 Nos. 1–2, Pergamon Press, Oxford and New York (1999).

[5] COOPER, J.R., ICRP Guidance on Radioactive Waste Disposal, paper presented at IAEA Specialists' meeting to resolve issues related to the preparation of Safety Standards on the Geological Disposal of Radioactive Waste (Vienna, 18–22 June 2001).

[6] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Protection of the Public in the Event of Major Radiation Accidents: Principles for Planning, Publication 40, Annals of the ICRP Vol. 14 No. 2, Pergamon Press, Oxford and New York (1984).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Critical groups and biospheres in the context of radioactive waste disposal, Fourth report of the Working Group on Principles and Criteria for Radioactive Waste Disposal, IAEA-TECDOC-1077, Vienna (1999).