Abstract: There are good reasons why ICRP should revisit the issue of solid radioactive waste disposal after the new recommendations have been established. One reason is the relation between radiation protection and the concept of sustainable development. Since the post-closure regulations determine the maximum burden for future generations at the disposal site, it is natural to make such a link. If we assume the continuation of the practice of nuclear power production or an alternative production with equivalent risk burdens, it is natural to consider the combined effect of present and future activities, particularly for long-lived radioactive waste. This leads to a suggested margin for dose to the public from a single repository. Another issue is the biosphere assumed in the assessment of exposure from a hypothetical outflow from the repository in the future. The existing regulations require dose or risk to be determined in most national standards. The issue of the future biosphere therefore cannot be avoided. However, if several possible future human activities in alternative biospheres have to be assumed in reviewing if the standard is met, the process can be said to take future generations need into account, also in harmony with the sustainable development.

1. Introduction

Since the publication 1990 of The International Commission on Radiological Protection ICRP’s general recommendations [1a], a number of important steps have been taken relating to waste management and performance assessment for radioactive waste disposal, in particular ICRP 81 [1b]. The newly suggested ICRP general recommendations, published in April 2003, do not specifically cover radioactive waste disposal. However, the area waste of disposal of long-lived waste is presently subject to an energetic societal debate and it is important that disposal issues are brought forward and also consolidated within the new recommendations. A few important areas are discussed below, some more fundamental, and some primarily technical. Future ICRP comments on these issues would be welcome for the waste management, and in particular the performance assessment community.

2 Risk and dose as performance assessment endpoints

In the last decades, and in particular after the US National Academy of Sciences, NAS, study about health based regulation for Yucca Mountain [2], national post-closure standards worldwide have expressed their endpoint quantity as dose or risk. Risk is defined both by ICRP [1c] and NAS [2, glossary], as the probability of adverse health effects from a dose, and it includes the probability of receiving the dose. The use of health-based criteria implies that some kind of human activity in some kind of biosphere must be assumed.

3 Radiation protection and sustainable development

An important issue is the principle of sustainable development, mentioned in ICRP’s new recommendations on protection of the natural environment. This strategy can be continued further in waste management by its application to exposure from a repository for long-lived waste. The principle has been defined by the Brundtland Commission as: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [3].
Most people agree with our philosophical point of departure, that we would not accept a level of protection for people, i.e. individuals from the public, in the future that is different from today’s standards. That is a necessary condition for setting requirements on today’s practices with long-term consequences such as final disposal of long-lived waste. However, another components often forgotten but equally important is the long-term consequences from similar practices in that part of the future lying before the assumed time of the future test person. To put it another way,

“If we assume an outflow from a repository with an inventory from 50 years of energy production, how should we treat hypothetical outflows from repositories in the next 9950 years, in the assessment of the dose to a person living 10 000 years into the future?”

If the (probability and/or magnitude of) future outflow is so high, that we have to assume that no other risk burden is attributed to the test person between the time of closure and 10 000 years into the future, then we have denied “future generations to meet their own needs”

One way of taking this principle into account is to assume a repository for every 50 year period, i.e. 200 repositories in 10 000 years and consider the possibilities of an overlap of exposure for an individual at the surface. The assumption with several repositories should not be taken too literally, however. It simply represents an aspect of sustainable development in the form of a steady state risk load. If future generations solved their energy problems in another way, should we assume that the risk load diminishes, or should we assume that what is acceptable today must be acceptable tomorrow. If we accept an activity, licensed and properly regulated, why not assume it may continue, as a starting assumption for our calculation of future burdens? In that case, the projected maximum release we can accept must be low enough to allow “future generations to meet their own needs”, that is to continue the practice along with its benefits and burdens.

The result of a calculation of the combined burdens from activities now and in the future can be done in many ways, reflecting a large numbers of additional assumptions, but it would require some sort of “partitioning upon partitioning” starting from 1 mSv/year, where the first partitioning take into account a number of simultaneous practices and the second the additional element of integration over time. The Swedish Radiation Protection Authority, SSI, has reasoned along these lines in setting up the radiation risk standard for final disposal [4].

4 The problem of prediction

When the idea of prediction in the geological domain is transferred to the biosphere, the need for a predicted future gives rise to both confusion and – worse – to the feeling that the lack of credibility of such prediction may “contaminate” the more reliable assessments of geological parameters, as given in Table 1 below, inspired by a publication from the Organisation for Economic Co-operation and Development’s, OECD, Nuclear Energy Agency, NEA [5], following the principle that a chain is not stronger that the weakest link.

Table 1. Years of post-closure predictability for a repository with long-lived waste

<table>
<thead>
<tr>
<th>Barriers, host rock</th>
<th>Geohydrology</th>
<th>Surface processes</th>
<th>Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 000 –1000 000</td>
<td>10 000 – 1000 000</td>
<td>100 – 1000</td>
<td>10?</td>
</tr>
</tbody>
</table>

Observe that Table 1 captures ranges over which different processes are reasonable stable. There may still be large uncertainty over how those processes work even in a period of relative stability.
SSI initiated the international BIOMOVS-project (Biosphere Model Validation Study) in which different models for biosphere modelling were compared and “validated” (validation means here to check that predications comply with observations). The project’s first meeting was held in Basel, Switzerland, October 1985. The project had an international follow-up, BIOMOVS-II, and there have also been recent advances in biosphere modelling as a result of the efforts of the Biosphere Model Assessment (BIOMASS) program, under the auspices of the International Atomic Energy Agency (IAEA). During these projects issues about the future biosphere and society have been debated intensively during several decades, but these groups of environmental experts have only had a limited overlap with the experts working with the total system safety analysis, such as the OECD/NEA working groups, the former Performance Assessment Advisory Group, PAAG, and the present Integration Group for the Safety Case, IGSC. It follows from this that, in addition to building up a technical understanding and modelling capability of radionuclides’ behavior in the biosphere, it is necessary that appropriate assumptions be made about future human behavior and biosphere, and that the solutions found can be broadly acceptable. IGSC has recently held topical seminars highlighting the biosphere in order to bring the disciplines closer together.

Part of the problem presented by the uncertainty of the future society and biosphere can be avoided by the use of an interpretation of sustainable development as explained below. In this concept, the future biosphere and society are treated as a subjective, rather than an objective, phenomenon.

5 A biosphere for sustainable development

ICRP 81 recommends the use of a reference biosphere with today’s conditions for demonstration of compliance. There is no justification for this choice given in the recommendations, but it is the same as has been suggested by many authorities, e.g. the Swedish Radiation Protection Authority’s own post-closure regulations. This choice is intuitively sound, in that it refers to a known and consistent society, and it is a natural reference for all other safety work in society.

The requirement from the Brundtland Commission, in terms of a repository for long-lived solid waste, is thus that risk from a hypothetical outflow of radioactive substances from a repository must meet the risk limit for a number of scenarios for the biosphere and society, such that they allow future generations to fulfil their needs within a broad spectrum of human activities and environmental conditions. Looking at the future this way excludes any need for prediction. The future conditions are seen as results of conscious choices constrained by consequences, i.e. risks, from the repository’s possible releases, which in turn are limited by the regulatory requirements. Observe that there is no easy way to define or limit the “broad spectrum of human activities..”. The main difference, introduced by the view of sustainable development, is that decisions about appropriate assumptions is taken out of the realm of predictive science and into that of societal judgment.

6 The technical issue of test person(s) in the distant future

The critical group is defined in the general recommendations in ICRP 26 [1d]. It may be used in connection with demonstrating compliance with a dose limit and the dose should be taken as the mean dose in a “reasonable homogeneous group” as explained further in ICRP 43 [1e]. ICRP goes on in the same publication (ICRP 43) to say that “in an extreme case, it may be convenient to define the hypothetical group in terms of a single hypothetical individual, for example when dealing with conditions well in the future which cannot be characterised in detail”.

In ICRP 81, dealing specifically with long-lived waste, the Commission has not used this idea from Publication 43 but refers to the critical group as if it consisted of a group of persons. In the
authors’ opinion, the notion from Publication 43 is far better, e.g. for educational purposes. The condition of the distant future can easily result in endless speculation, and on top of that the term “group” may invite speculation as to different behaviour of different individuals within an already doubtful scenario. It is an indication of the concept’s elusiveness that it was the only item on which the National Academy’s team could not come to a unanimous agreement [2, Appendices C and D]. Exposure from a source of any group of people living today can be calculated using hypothetical persons, but measurements can be made at any time to verify the calculations. This is not true for persons exposed in the distant future. The variability within a group existing today can be studied, but it has to be assumed for a group the distant future, in addition to the biosphere and societal conditions.

By taking today’s society and biosphere as the regulatory point of departure, the US agencies The Environmental Protection Agency, EPA and The Nuclear regulatory Commission, NRC have avoided speculation about the distant future. The US EPA in writing its standard for Yucca Mountain focused the regulatory endpoint of an individual as recommended in ICRP 43 whose dose would be near, but not at, the upper end of what would be the critical group for a similar exposure today. Hence the name given to this hypothetical person: the Reasonably Maximally Exposed Individual.

### 7 Conclusion

The nuclear waste programs are in some countries (Finland, Sweden) in a late phase, and international consensus on all aspects of the performance assessment is important. In the European Union, a draft directive on safety is being proposed by the European Commission with a preamble stating that “pursuant to Article 2(b) /of the EURATOM treaty/, the Community has the task of establishing "uniform safety standards to protect the health of workers and the general public and ensure that they are applied". Although the statement is probably directed primarily at reactor safety work, the directive is formally valid for all installations including nuclear repositories. It is therefore valuable for all stakeholders in the area of final disposal, that ICRP both clarifies its new recommendations the area of waste management and also expands on some of them to incorporate the principle of sustainable development.

### 8 References

1. ICRP Publications.

