BIOPROTA

Key Issues in Biosphere Aspects of Assessment of the Long-term Impact of Contaminant Releases Associated with Radioactive Waste Management

Report of the Seventeenth BIOPROTA Workshop

Madrid, Spain

25-26 May 2015

Version 2.0, Final
October 2015

PREFACE

BIOPROTA is an international collaboration forum which seeks to address key uncertainties in the assessment of radiation doses in the long term arising from release of radionuclides as a result of radioactive waste management practices. It is understood that there are radio-ecological and other data and information issues that are common to specific assessments required in many countries. The mutual support within a commonly focused project is intended to make more efficient use of skills and resources, and to provide a transparent and traceable basis for the choices of parameter values, as well as for the wider interpretation of information used in assessments. A list of sponsors of BIOPROTA and other information is available at www.bioprota.org.

The general objectives of BIOPROTA are to make available the best sources of information to justify modelling assumptions made within radiological assessments of radioactive waste management. Particular emphasis is to be placed on key data required for the assessment of long-lived radionuclide migration and accumulation in the biosphere, and the associated radiological impact, following discharge to the environment or release from solid waste disposal facilities. The programme of activities is driven by assessment needs identified from previous and on-going assessment projects. Where common needs are identified within different assessment projects in different countries, a common effort can be applied to finding solutions.

This report describes presentations and discussions held during the seventeenth annual BIOPROTA workshop held from 25-26 May 2015. The workshop was hosted by Ciemat in Madrid, Spain. Technical inputs were provided by a wide range of organisations via presentations and discussions, as described in this report.

The report is presented as working material for information. The content may not be taken to represent the official position of the organisations involved. All material is made available entirely at the user's risk.

Version History

Version 1.0: Draft workshop report prepared by Karen Smith (RadEcol Consulting Ltd) based on participant contributions, 21 August 2015.

Version 2.0: Final workshop report prepared by Karen Smith (RadEcol Consulting Ltd), taking into account participant comments on the version 1.0 report. Distributed on 12 October 2015.

CONTENTS

1. INTRODUCTION

The seventeenth BIOPROTA workshop was hosted Ciemat in Madrid, Spain from 18-19 May 2015. The support of Ciemat in the organisation and hosting of the workshop is gratefully acknowledged.

BIOPROTA participation is aimed at national authorities, agencies and other organisations, including technical support organisations and independent research institutions, with responsibilities and interests related to achieving safe and acceptable radioactive waste management. The member organisations at the time of the meeting included:

- ANDRA, France
- ARAO, Slovenia
- BFS, Germany
- CIEMAT, Spain
- EDF, France
- ENSI, Switzerland
- FANC, Belgium
- IRSN, France

JGC, Japan

- KAERI, Korea
- LLWR, UK
- NAGRA, Switzerland
- RWM, UK
- NRPA, Norway
- NUMO, Japan
- NWMO, Canada
- POSIVA, Finland
- SCK·CEN, Belgium
- SKB, Sweden
- SSM, Sweden

There are additionally two academic members; Oregon State University, USA, and the University of Life Sciences, Norway.

1.1 OBJECTIVES AND SCOPE OF THE WORKSHOP

The objectives of the workshop were:

- to update interested parties on progress since the last meeting in May 2014 on the various activities and projects supported through BIOPROTA;
- to provide an informal forum for continuing exchange of information and discussion about biosphere topics of interest; and
- to identify common scientific issues relating to the assessment and analysis of safety for radioactive waste disposal facilities, upon which collaborative tasks may be developed.

1.2 PARTICIPATION

The workshop, hosted by Ciemat in Madrid, was attended by 21 participants from 10 countries, representing a range of operators, regulators, researchers and technical support organisations. Participants are listed in Appendix A.

1.3 REPORT STRUCTURE

Section 2 of this report summarises the presentations made by participants. Section 3 then provides an overview of progress in BIOPROTA activities since May 2014 and an overview of parallel international work programmes. Future work programme suggestions and forum arrangements in 2015-16 are presented in section 4.

2. WORKSHOP PRESENTATIONS AND DISCUSSIONS

Presentations from workshop participants on their biosphere programmes, issues and uncertainties are summarised below, including related discussions.

2.1 CONSIDERATIONS FOR IMPROVING THE BIOSPHERE ASSESSMENT METHODOLOGY AND THE ASSOCIATED CONCEPTUAL AND MATHEMATICAL MODELS FOR APPLICATION TO LLW/ILW RADIOACTIVE WASTES IN SPAIN

Danyl Perez-Sanchez presented.

The El Cabril disposal centre for low and intermediate level waste (L/ILW) in the south of Spain has been operational since 1992, with a facility for very low level waste (VLLW) being operational at the same site since 2008. The last safety assessment for the site was undertaken in 2002. An update is therefore required to take account of VLLW disposal.

Disposal of L/ILW is to a near surface facility. Wastes from hospitals, research centres and industry arrive to the waste conditioning building for treatment and conditioning. Wastes from nuclear power plants arrive ready conditioned and are assigned directly to a temporary storage facility. Wastes requiring conditioning are placed in drums that are filled with concrete. Wastes classified as VLLW are largely solid in form and arrive at the facility in sacks, drums or containers. VLLW is not uniform therefore and efforts are made to ensure that wastes are safely placed. No additional treatment or conditioning is undertaken for VLLW. As disposal areas are filled, various layers are added to cover the disposal areas, the last being topsoil. These are less defined barriers than are used for the L/ILW disposal area, which additionally includes leachate recovery to allow for monitoring. A 60 year site surveillance and control phase is in place for the VLLW disposal facility.

In the update to safety case it is the intention to improve the modelling approach for different scenarios such as the groundwater pathway and human intrusion and to update human land use and diet assumptions. There is also the intention to look in more detail at special radionuclides.

The normal evolution scenario considers the infiltration of rain water and release of radionuclides in infiltrating water to groundwater. Both free drainage and upwelling of groundwater are considered. The general scheme of assessment is illustrated in Figure 2-1. Additional scenarios for consideration in the updated safety assessment are illustrated in Figure 2-2.

In terms of model developments, soil-plant models are to be further developed to improve the level of detail considered and parameters relative to climate change. The required timescale of assessment is 10,000 years, but it is intended that a 100,000 year timeframe will be adopted to allow uranium-series radionuclides to be evaluated. This extended timeframe drives toward climate change being specifically evaluated in the assessment. Information on climate change is also valuable in supporting facility design.

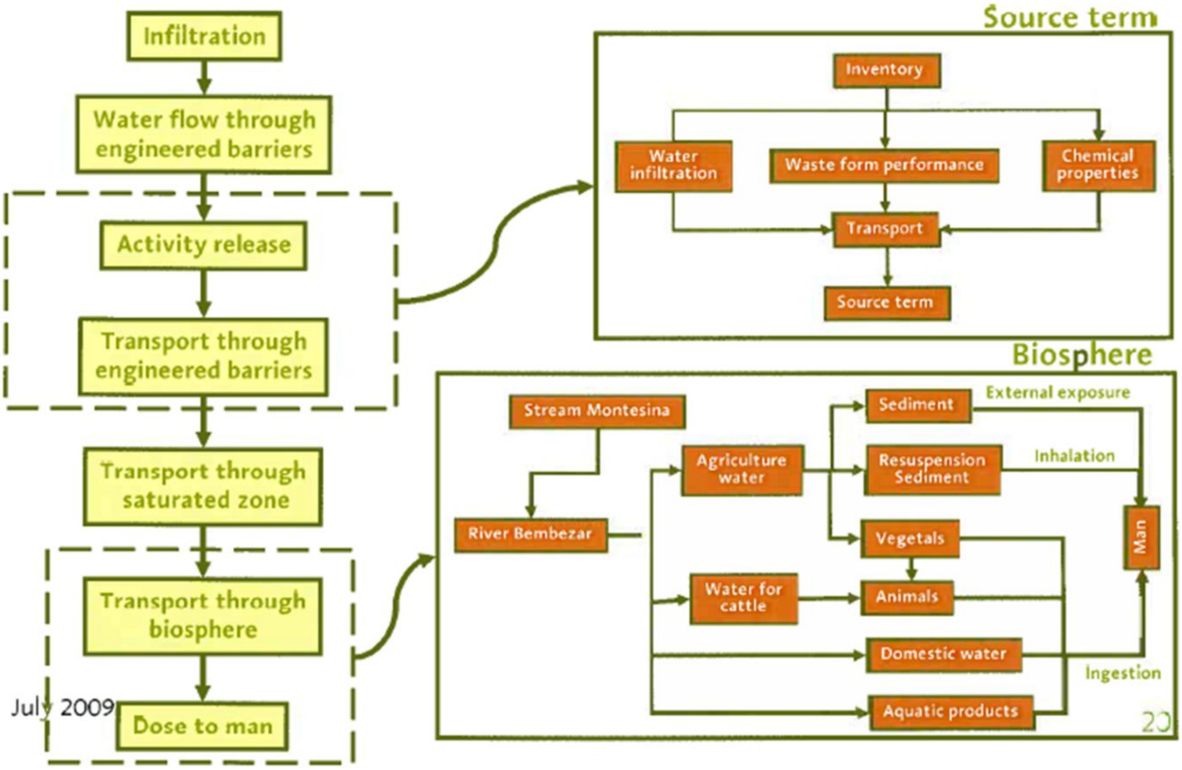


Figure 2-1. Illustration of the general scheme of the normal evolution scenario assessment.

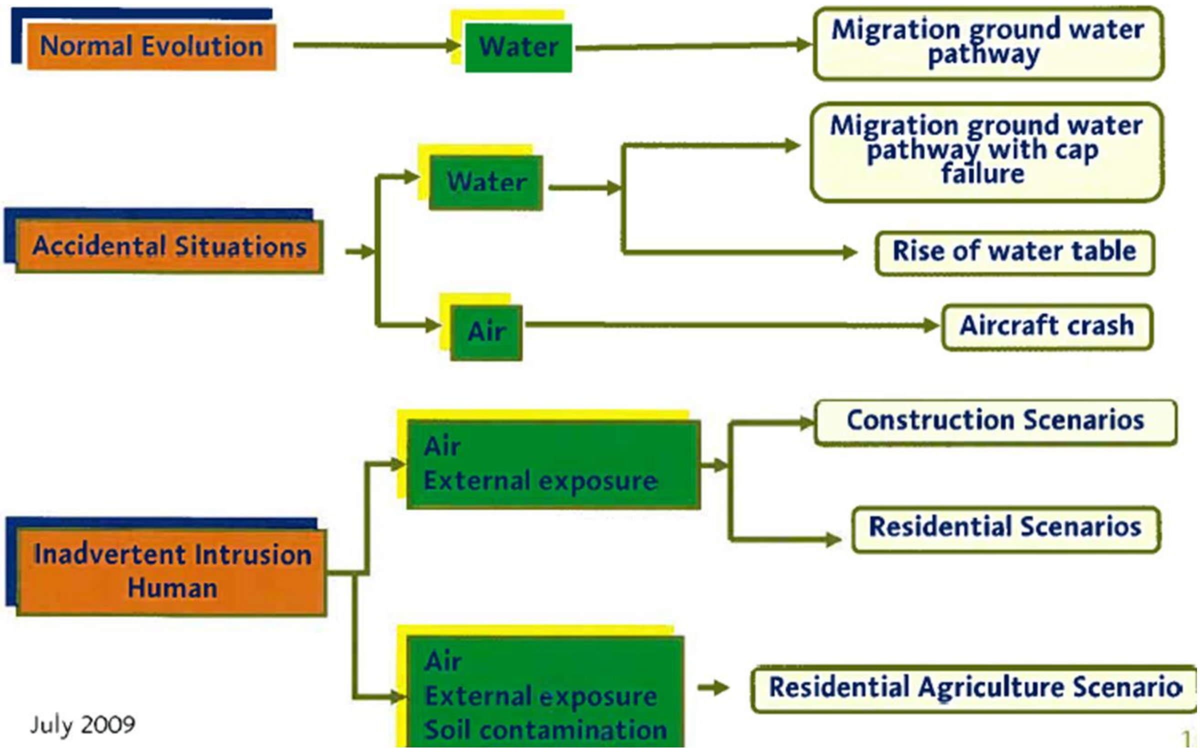


Figure 2-2. Exposure scenario selection for the updated El Cabril safety assessment.

A further issue to be addressed is the complexity that is required for assessment models; there is a large diversity with regard to model complexity depending upon the focus of each model. For example, some radionuclides have complex behaviour and special models are required to address these complexities. An illustration of the variation in complexity of different models is illustrated in Figure 2-3. How information from these different models should be extracted for application to the overall assessment requires careful consideration.

Traditional models, as described in Table 2-1, are commonly used in assessments, but recently, more dedicated models are being applied internationally in order to represent specific processes and allow individual radionuclide behaviour to be taken into account. An example specific model is the Ciemat soil hydrology model that is used to estimate seasonally varying water contents and fluxes through a multi-layer soil. The model operates in 1-D and can be linked to hydrological conditions at the site and how they vary under different climate states, such as varying temperature and precipitation. Input to the model can be precipitation/irrigation or upwelling of groundwater. The model considers the root profile of plants to more accurately evaluate plant uptake in relation to the concentration of radionuclides in different soil layers and throughout the growing season.

Figure 2-3. Summary of the complexity of different assessment models.

Traditional models	Advanced models	R & D Models
• Early stages of waste disposal planning, generic or limited site specific detail • Limited spatial extent • 1, 2 or 3 compartments • Simple interpretation of local hydrology • Annual averages of transfer processes • Soil-plant model by concentration ratio (CR)	• Mature stages of waste disposal planning, detailed site specific information • Landscape models – multiple linked biosphere objects • Multiple compartments, structure in soil column • Detailed local hydrology • Annual averages of transfer processes • Soil-plant model by concentration ratio (CR), some dynamic modelling of plants in natural ecosystems	• Models for specific nuclides and/or specific features events or processes (e.g, redox and volatilisation) • Scope here is for soil column processes, specifically variable saturation with movements of the water table • Multiple compartments • Review of representation of hydrology (role of bio-turbation and solid material transport) • Monthly processes to determine transfer rates • Dynamic soil/plant uptake and/or concentration ratio

As part of the model development tasks that are planned, it is intended that the 1-D model will be extended to 2-D to allow the hill-slope landscape at El Cabril to be taken into account and to extend the model to different radionuclides. Development to allow erosion to be consider under a drier climate is also planned and there is an ambition to undertake model testing and validation exercises, such as model inter-comparison tasks as organised previously through the BIOPROTA programme. The behaviour of redox-sensitive radionuclides under changing climate conditions is also to be evaluated; the model is considered a powerful tool for exploring the behaviour of radionuclides under different redox conditions.

Currently, the El Cabril site is subject to a Csa climate and, according to the BIOCLIM low greenhouse gas scenario, this will be followed by a rapid transition to a much dryer and warmer climate (BWh) over the next 300 years. This is then followed by a moderately rapid cooling transition, over a period of around 5,000 years with subsequent cycling between warmer and cooler climate phases. The IAEA MODARIA programme has revisited climate evolution and approaches to downscaling global climate to specific sites. The information produced as a result of this programme is to be applied to El Cabril to update estimates of climate evolution. Once climate conditions have been established, assessment models will be used to gain an improved understanding of water drainage through barriers and the waste disposal areas and groundwater recharge in the vicinity of the site. As input to this, some information on how the different climate conditions affect model parameters, such as increased or decreased precipitation and its effect on soil hydrology and plant growth, is required.

Further planned tasks include updating of the Ciemat C-14 model to take account of information and knowledge gained from the various BIOPROTA C-14 activities and to adapt the information for Spanish conditions, both present and future. In particular, specific consideration is to be given to the behaviour of methane and carbon dioxide in soils under semi-arid conditions and the passage of carbon dioxide through a sparse vegetation canopy. Furthermore, whilst non-human biota assessments are not currently mandatory in Spain, work is ongoing to evaluate the applicability of the EC ERICA Assessment Tool to Spanish conditions.

A series of recommendations have been submitted to ENRESA by Ciemat for activities to be taken forward in support of an updated safety assessment for the El Cabril site. The recommendations are as follows:

- Consideration should be given to how the current 1-D soil-plant models developed by Ciemat should be extended to 2-D hillslope models and how both the 1-D and 2-D models should use flow information obtained from 3-D models of surface-water catchments.
- Consideration should be given to the development of an erosion model applicable at El Cabril that is able to address both generalised and gullying erosional processes.
- The existing 1-D model should be adapted and used to explore the significance of using a kinetic representation of sorption and desorption in soils, and consideration should be given to developing and parameterising the 1-D model for additional radionuclides of radiological significance in VLLW and L/ILW.
- Consideration of climate change and future scenarios in the safety assessment will continue, including adaptation and application of the methodology to the whole disposal system at El Cabril.
- The latest models for the behaviour of C-14 in soils and plants should be reviewed and adapted to environmental conditions that may occur in Spain over about the next 10,000 years, with a particular emphasis on conditions that may occur at El Cabril.
- The applicability of the ERICA Tool to conditions in Spain, and particularly those conditions that exist, or may exist in the future, at El Cabril are being evaluated, and modifications or updates to the underlying dosimetric and transfer factor databases made, as appropriate.

Discussion

ENRESA has previously considered the non-radiological hazards associated with radioactive waste storage, but this is not a topic that Ciemat has evaluated to date. It has been recognised that hazards can sometimes be higher for hazardous rather than radioactive materials and that the matrices used to prevent radionuclide release can lead to greater leaching of some conventional contaminants. Should consideration be given to the non-radiological hazards of the wastes, the same models would be applied.

The multiple soil compartments in the Ciemat 1-D model relate to soil characteristics such as humic content and pH. Each soil layer is connected to that above and below according to its characteristics. For those radionuclides affected by redox conditions, consideration has to be given to how speciation should be represented in relation to the various factors that affect speciation, such as pH. The Ciemat approach is not to consider speciation specifically, but rather to use a Kd approach that links soil hydrology and humic content of soil with the soil hydrological regime being the key factor. A paper has been published that explains why the hydrological regime of the soil is a good representation for soil characteristics such as pH within a multi-soil compartment model. Water is also an important focus in the Spanish assessment due to the dry climate. Occasional storm events can occur that result in hydrological changes that can affect the system for several years. The water content of a soil will have implications for radionuclide diffusion and volatilisation, an important process for Se-79.

When considering irrigation, assumptions relate to specific crops. It is the irrigation pathway that is the key scenario leading to dose, rather than groundwater upwelling although the importance of the different pathways will be affected by which radionuclides are being considered and the biosphere itself.

The complexity required for a model is very radionuclide dependent. For example, for radium, there is little difference in output between simple and complex models. However, for selenium, a large difference in output can occur due to processes affecting selenium behaviour, such as methylation, being taken into account in more complex models.

By taking into account new knowledge and information on radionuclide-specific behaviour, assessment results can be changed considerably. For example, and largely as a result of work undertaken within BIOPROTA, C-14 dose results have been reduced by two orders of magnitude. Such reductions in dose, based on justifiable revisions to models, can be very useful when considering disposal of graphite waste streams. Such changes as a result of moving from a traditional to more complex model approach may not affect facility design (the El Cabril facility already being in operation), but waste acceptance criteria could be revised.

2.2 CURRENT STATUS AND FUTURE PLAN FOR BIOSPHERE MODELLING AT KAERI

Jongtae Jeong presented.

The KAERI biosphere model was developed in GoldSim around five years ago and has been used to evaluate the feasibility and acceptability of radioactive waste disposal plans. A five year research and development programme is now due to be developed.

There are two reference disposal systems in Korea:

- KRS – a system for the direct disposal of spent nuclear fuel; and
- A-KRS – a system for the disposal of pyro-processed wastes.

The different disposal reference systems are illustrated in Figure 2-3. Disposal in the KRS will be at a depth of around 500 m. Since there are both Candu and PWR reactors in Korea, different areas of the repository will be assigned for the different spent fuels. Disposal of waste canisters in the A-KRS facility will be at a depth of around 200 m for metallic wastes and 500 m for ceramic wastes.

KRS: direct disposal of SF

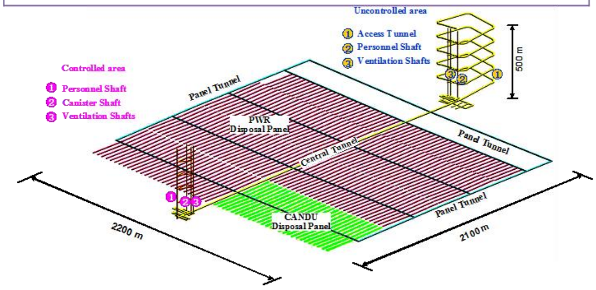
- **Disposal Canister**
  - 50 mm copper-nodular cast iron
  - Manufacture: Roll and weld
  - Lifetime: 100,000 years
- Buffer
  - **Domestic Ca-bentonite**
  - Dry density: 1.6 g/cm^3
  - Thickness: 50 cm
  - Thermal conductivity: 1.0 W/mK

Vertical deposition: 40 m tunnel spacing	
• Number of disposal tunnels	377
• Length of a tunnel	251 m
• Disposal Area ✓CANDU (16,000 MtHM) ✓PWR (low burnup, 20,000 MtHM)	~ 4.6 km^2 ~ 0.5 km^2 **~ 5.1 km^2**

A-KRS: pyro-processed waste

- **Disposal Canister**
  - 10 mm copper-nodular cast iron
  - **Manufacture: Cold spray coating**
  - Lifetime: 1,000 years (determined by radiotoxicity)
- Buffer
  - **Domestic Ca-bentonite**
  - Dry density: 1.6 g/cm^3
  - Thickness: 36 cm
  - Thermal conductivity: 0.8 W/mK

Horizontal deposition: 25 m tunnel spacing	
• Number of disposal tunnels	16
• Length of a tunnel	200 m
• Disposal Area	**~ 0.078 km^2**
• Comparison with direct disposal (0.078 :5.1)	~1/70



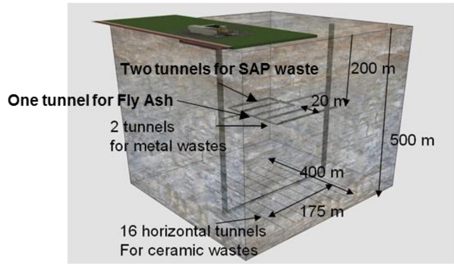


Figure 2-3. The KRS and A-KRS disposal systems.

Safety guidelines for high level radioactive waste have not yet been finalised in Korea. Draft guidelines were released in 2012 by the Nuclear Safety and Security Committee and are currently under review. The safety goals stipulated in the draft guidelines are that the total annual risk for the representative person resulting from the radiation exposure should not exceed 1.0×10^{-6}/y and the expected radiation exposure for the representative person for each scenario should not exceed 10 mSv/y. The guidelines therefore require the probability of exposure scenarios to be considered. It is further stipulated in the draft safety guidelines that the effective dose rates have to be assessed for the representative person and a risk factor value of 0.05/Sv is to be used to convert the dose rate to risk. Furthermore, scenarios have to be developed by analysing systematically important phenomena, processes, and events that represent the characteristics of repository system and may contribute to a high exposure dose rate.

A total system performance assessment programme has been undertaken to check the suitability of the reference designs for both systems under a range of different scenarios, including seismic events and human intrusion. The modelling scheme for the assessment is illustrated in Figure 2-4 and is comprised of near-field transport, far-field transport and biosphere modelling modules. Radionuclides, released from the repository, will be transported through internal fractures within the geosphere and be discharged to river water sediment or marine water sediment. Alternatively, contaminated water can be extracted from a groundwater well for irrigation. A range of different processes are considered, including infiltration, erosion and evaporation. Three exposure groups are considered in the assessment; marine fishermen, river fishermen and a farming community. The exposure pathways for each exposure group are illustrated in Figure 2-5.

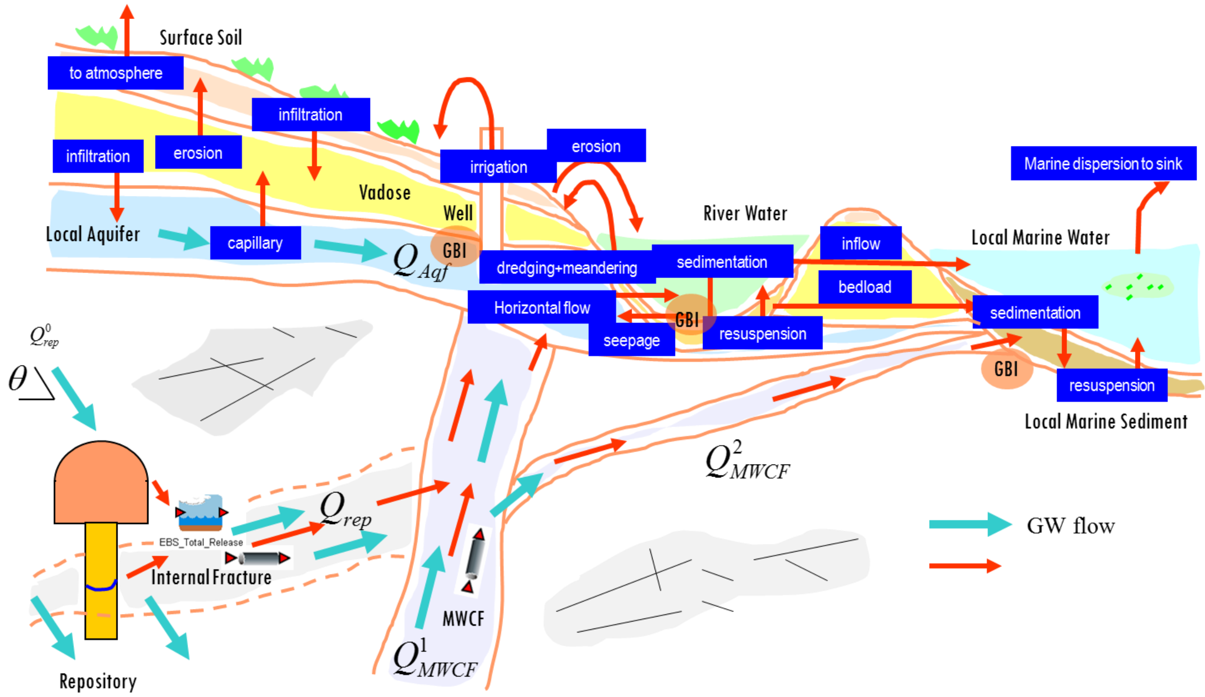


Figure 2-4. Modelling scheme for the KAERI total system performance assessment.

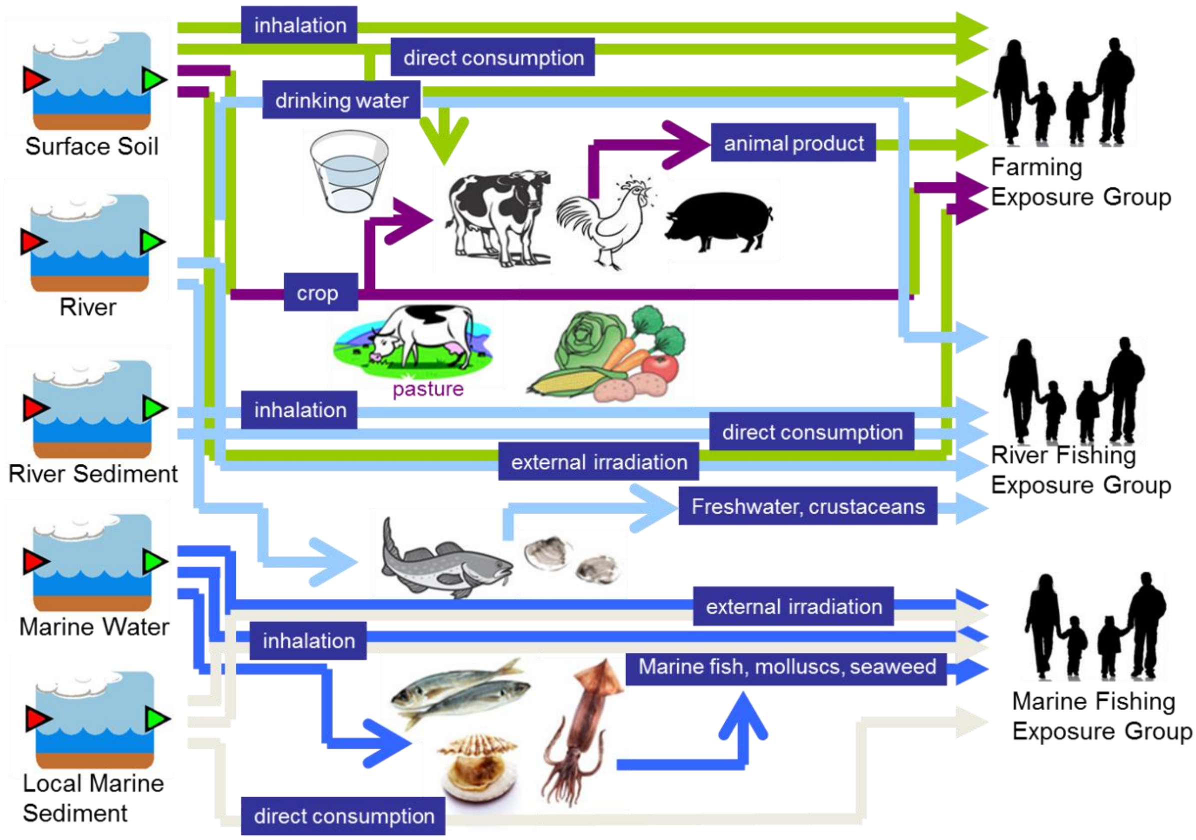


Figure 2-5. Exposure groups and associated exposure pathways.

Input data to the biosphere model have been derived from the Korean statistics office or from literature references, laboratory experiments or from the underground rock facility. It is assumed that all radionuclides are in a state of equilibrium in the geosphere-biosphere interface with transport models being based on a unit concentration release over a year. The source term is then used to evaluate actual radionuclide concentrations in the biosphere. Results illustrated that peak dose rates were all lower than the 10 mSv/y safety goal and were also below exposure rates associated with natural radioactivity in local bedrock.

The main food consumed in Korea is rice and the food chain resulting from a farming group was considered to be important. However, little difference in dose is observed for fishing groups either with or without rice consumption. The sensitivity of the results to rice production area and consumption rate has been investigated through probabilistic analysis. As the consumption rate increases, there is a rapid increase in the peak dose rate. No trend was observed in relation to the agricultural area used for rice production.

There are currently plans to update the biosphere models, and a research and development programme is being prepared. Models will be updated with regard to features, events and processes for the geosphere-biosphere interface and more detailed models for this interface are required, such as dynamic models for each geosphere-biosphere interface rather than the current equilibrium approach. There is also an objective to consider the impact long-term evolution of the landscape and climate on biosphere modelling.

Discussion

No site has yet been selected in Korea for high-level waste disposal and, as such, for the purposes of undertaking feasibility assessments, the area around KAERI has been selected as a representative site. This area is also the location of an underground research tunnel that provides some assessment data. Data for aquatic systems have been derived from other sites in Korea and/or from literature sources. The modelling scheme and information on how to apply the models to a system may be passed to the disposal system implementer once a site has been selected; KAERI being a research and development institute rather than an operator.

The three exposure scenarios were selected following a FEP analysis to identify the most important scenarios. The canister design is based on the Swedish concept and a 50mm copper container is currently considered, although a much lower thickness is likely to be needed to achieve the safety function. For example, NWMO consider a 1.3 mm thickness of copper is sufficient to achieve safety over a 100,000 year period.

In Korea, fuel from Candu nuclear fuel reactors are currently planned to be placed directly in the spent fuel repository. The fuel from the PWR reactors is reprocessed with plutonium being retained for use in Candu reactors.

There is not currently a requirement for biota dose assessments to be undertaken in Korea and protection of the environment has not been raised by the general public. Nonetheless, some work is ongoing in this area as it is recognised that protection of the environment may arise as an issue in the future, leading to a regulatory requirement for assessments to be undertaken. International developments in this field are therefore being followed.

2.3 PROGRESS WITH THE ENVIRONMENT PROJECT AT ANDREEVA BAY

Anna Filonova presented.

In response to a Russian Federal Government Statement, the Federal Medical Biophysical Centre (FMBC) of Russia was established in 2007. The objective of the FMBC is to provide scientific-based support on radiation safety, survey and dose assessment of workers and members of the public in areas surrounding nuclear power plants, former navy bases, uranium mines, radioactive waste and spent nuclear fuel treatment facilities, nuclear defence facilities and nuclear legacy sites, including areas affected by the Chernobyl nuclear power plant accident. The key scientific research areas are in radiation health physics and epidemiological studies. Experts at the FMBC develop and implement tasks in relation to radiation protection of workers and members of the public around facilities.

There are three SevRAO sites (Figure 2-6). SevRAO-1 is located at Andreeva Bay in the Russia Kola Peninsula, on the border with Norway. SevRAO-2 is located at Gremikha and SevRAO-3 is located at Saida Bay. All three represent complex legacy sites that were constructed for nuclear submarines and were a location for the storage of nuclear fuel. All three sites are now categorised as storage sites that are undergoing remediation. The Saida Bay site has been selected for spent nuclear fuel storage and disposal.

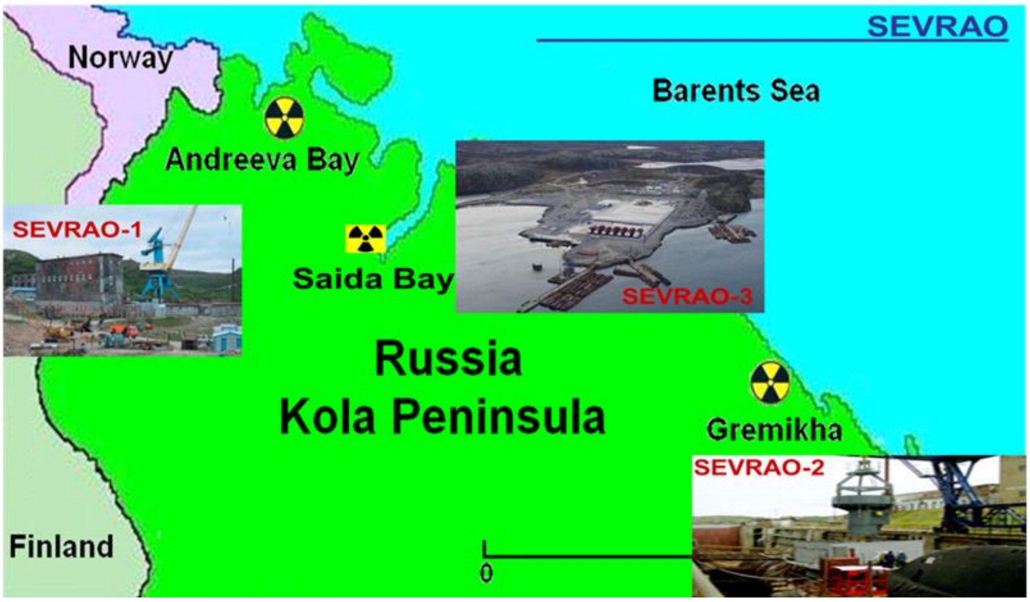


Figure 2-6. Location of the SevRAO sites within the Russian Kola Peninsula.

Andreeva Bay is a coastal site that currently stores around 1.3E17 Bq of spent nuclear fuel and 6E14 Bq of radioactive waste. The remediation of these storage areas are important activities for the FMBA, which is working closely with the NRPA. The NRPA has a safety regulation plan to improve radiation safety and safe nuclear energy use in Russia. A cooperation agreement between the FMBA and NRPA was signed in 2008. Overall, collaboration has been ongoing since 2004 between NRPA and Russia with 24 collaborative projects being undertaken in the period to 2014. These projects have included independent analysis of the situation at legacy sites and undertaking dose assessments for workers and members of the public, radiation threat assessments and development of regulatory control documents and emergency responses. There have also been projects to develop GIS systems of radiation contamination areas.

A threat assessment was undertaken in 2004 that considered risks associated with poor infrastructure of storage areas for radioactive waste and spent nuclear fuel. The assessment of regulatory readiness for the implementation of radiation safety justified a development plan for infrastructure in support of spent fuel and radioactive waste management. In the 10 years since the project began, considerable remediation activities and infrastructure development are evident (Figure 2-7).

Figure 2-7. Illustration of 10 years of remediation and infrastructure development activities at Andreeva Bay.

The main task of the Environment project is to evaluate the levels of radionuclide contamination on the Andreeva Bay site and assess the appropriateness of criteria for the remediation programme for radiation safety of the environment. As part of this, a GIS map of contamination has been developed. Representative organisms have been selected for the control area to allow environmental impacts to be evaluated. The species have been selected on the basis that they are typical of the local area and live directly on the controlled site. Monitoring at the site has been underway since 2005 and radiation impact is considered relative to three different areas that vary in their level of contamination and exposure pathways:

- Area close to Building 5: practically no soil contamination, dose arises from external exposure from Building 5 and internal exposure of representative organisms is ignored.
- Area behind Building 5 (dry brook bed): dose arises from soil contamination and both internal and external exposure are taken into account.

- Third site: local areas of soil contamination and additional sources of external exposure are present. Dose calculation considers both external and internal exposure pathways.

If the remediation criteria are found not to be appropriate then recommendations for improvement will be made.

The monitoring programme has included a wide range of environmental media, including seaweeds, bottom fauna and flora. Gamma dose rates have also been routinely taken. The monitoring has not been focused solely on environmental protection, samples have also been taken in support of healthcare dose assessment for people.

The gamma dose rate on the site has been shown to be highly variable with the greatest dose rates being recorded in the control area that is currently subject to remediation activities. A positive trend over time has been noted in the reduction of upper bound gamma dose rate across the site (Table 2-2). Gamma dose rate is now largely governed by building and vehicle contamination. The results demonstrate therefore that the remediation activities are having a positive benefit at the site.

Table 2-2. Trend in gamma dose rate at Andreeva Bay (2002-2013).

Industrial site	Year of study			
	2002	2008	2010	2013
Supervision area	-	0.12 – 0.32	0.1-7.34	0.1-0.2
Control area	0.5-450	0.69 - 260	0.07-115	0.5-150
Background typical for the region		0.1-0.15		

Marine samples, taken at reference points in the off-shore area behind Building 5, show that concentrations of anthropogenic radionuclides slightly exceed background levels. A positive trend in reducing concentrations of radionuclides in seawater over the survey period has again been observed (Table 2-3).

Table 2-3. Trend in concentrations of anthropogenic radionuclides in marine media.

Radionuclide	Background concentrations	Year of study			
		2005	2008	2010	2013
Seawater, Bq/l					
Sr-90	0.004	0.26	0.2	0.025	0.005
Cs-137	0.006	0.03	0.33	0.043	0.015
Bottom sediments, Bq/kg					
Sr-90	0.5-12	-	5-16	3.1-10	11-44
Cs-137	11-29	30-600	18-160	22-140	19-160
Seaweeds, Bq/kg					
Sr-90	0.2-14	12-50	11-15	2.1-10	5.6-18.1
Cs-137	5-18	12-147	1.2-19	22-140	9.1-66

The concentrations of man-made radionuclides in soils and plants within the supervision area were found to be highly variable. Some of the samples collected have been analysed for plutonium contamination, in addition to Cs-137 and Sr-90. Concentrations in surface soils were an order of magnitude or more greater than in deeper soils. Future site investigation is on-going to assess the level of plutonium contamination across the Andreeva Bay site.

Dose rates to the representative organisms have been assessed, based on measured gamma dose rates and radionuclide activity concentrations in environmental media, using the ERICA methodology. In some areas where the concentrations in soil are highest the results indicate dose rates above the ICRP DCRLs corresponding to the relevant organism.

Contamination levels have also been calculated which, if present, would give rise to doses to humans corresponding to the regulatory dose constraints set for alternative remediation strategies. The dose rates to non-human biota at these contamination levels are, in most cases, below the ICRP DCRLs. The exceptions only occur in very local areas in the most heavily contaminated areas of the site which will in any case be remediated further for the purpose of human protection. It is concluded provisionally that the current protection measures taken within the existing remediation criteria are sufficient to meet protection objectives for the environment as represented by ICRP DCRLs.

A second Environment project is now underway that involves a comprehensive study of the environmental conditions around sites of temporary storage and an ecological assessment of the terrestrial system using bio-indicator methods. It is also intended that data will be obtained for bottom sediments in the coastal area and that dynamic contamination data for the site, including data for plutonium, will be obtained. A biodiversity survey of the reference species will also be undertaken and the ecological condition of the area will be assessed.

Discussion

The remediation criteria were developed in 2007 and no criteria were therefore in place at the start of the Environment programme. The targets for biota exposure selected were the ICRP DCRLs. The project to look at environmental impacts was small in relation to the work undertaken to ensure protection of workers at the site.

Once spent fuel and other radioactive wastes are removed from the site, residual contamination will be present in the ground. A decision will need to be taken as to whether to leave the contamination in situ to allow for radioactive decay or to remediate the area to prevent migration of mobile radionuclides to the coastal area; the coastal area is enclosed and sheltered and coastal erosion is not a particular issue for the site programme. Geosphere-biosphere modelling is therefore of interest to inform on the long-term site management programme. Monitoring data from both the geosphere and biosphere may also be useful to allow assessment models to be evaluated against data from a site.

Whilst radiation levels have been recorded in some areas of the site which could give rise to impacts on non-human biota, no direct impacts on the biota present are evident. Damage to the environment will however occur as a result of construction and other remediation operations. The dose assessment and continuing work will therefore provide valuable information in support of stakeholder dialogue on the risks associated with the site and surrounding areas and implications of remediation activities.

2.4 REGULATORY FEEDBACK ON BSA-2012 AND PLANS TO ADDRESS THEM IN BSA-2020

Lauri Parviainen presented.

Posiva submitted their license application for the construction of a spent nuclear fuel repository on the island of Olkiluoto to the Finnish Radiation and Nuclear Safety Authority, STUK, in 2012. After some questions from STUK for additional information, a statement on the safety case was given. This statement included 35 requirements. Three of the main questions arising from the review of the license submission related to the biosphere assessment. These questions are to be considered when updating the assessment for the 2020 submission for the operational license for the repository.

Regulatory requirement 2 focussed on climate development effects on the biosphere. As a result of this requirement, Posiva must evaluate in more detail the alternative possibilities of climate evolution and their impact on the repository. As such, three climate scenarios are to be considered for the 2020 license submission: temperate; periglacial; and glacial climate phases. The different climate scenarios will be modelled according to different CO_2 release scenarios.

Requirement 19 calls for the effect of the low and intermediate level waste repository to be included in the overall safety assessment. This repository was not included in the BSA-2012 assessment, but will be incorporated for the 2020 submission. This will require the addition of new contributing radionuclides such as Sr-90. Other effects from the incorporation of this repository to the safety case will require that an open system with no containment be considered and that chemical changes to the groundwater may occur and the impact on the spent fuel repository will need to be evaluated. New discharge locations to the surface environment will also need to be considered. Since there is no containment for the LILW repository other than concrete disposal boxes, the radionuclides from this facility are likely to dominate with regard to dose, being around an order of magnitude greater than those arising from the spent fuel repository.

Requirement 31 calls for Posiva to undertake a probabilistic sensitivity analysis through comprehensive calculations for different scenarios and for the migration of radionuclides in the biosphere, using an optimised landscape model. The important parameters for the biosphere assessment are also to be identified. Since there is a very high safety margin, based on the results of the BSA-2012 assessment, it is not envisaged that the uncertainty analysis will change the overall basic conclusions of the assessment.

In order to optimise the landscape model for the probabilistic analysis, biosphere object delineation is to be revised so that the overall number of objects is reduced to allow the use of probabilistic tools. The overall dose assessment will not be affected by reducing the number of objects since the main doses arise from objects close to the release locations and many of the biosphere objects in the BSA-2012 assessment were not contaminated. Croplands in particular were complex in terms of their delineation in the 2012 assessment and a more realistic approach is planned for the BSA-2020 assessment. Cropland delineation was performed by hand in the last assessment and it is hoped that a computerised approach can be used for the 2020 assessment. An example of how cropland objects may change between the assessments is provided in Figure 2-8. Results of the probabilistic analysis will be compared with the BSA-2012 results.

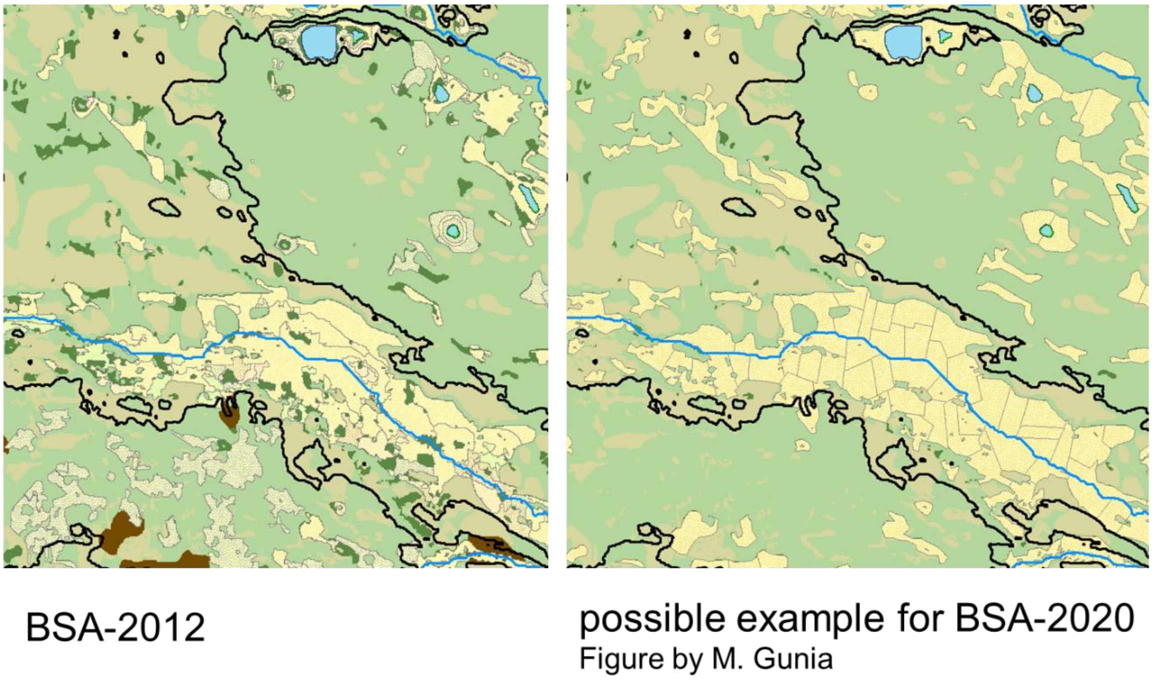


Figure 2-8. Biosphere object delineation, focussing on croplands, illustrating the BSA-2012 object delineation and possible approach for BSA-2020. Note that brown areas in the left figure relate to mires that have yet to be included in the right example figure.

STUK has also commented that, of the scenarios evaluated in BSA-2012, the variant scenarios with radionuclide releases to the south of the island were associated with the highest doses. As such, the effect of discharge location should be considered to a greater extent. The difference in doses in BSA-2012 between north and south release points was related to the aquatic environment to which the release occurred. In the north release, rivers were the receiving body whereas lakes were in receipt of discharges in the south. A greater dilution is associated with river releases. With the north of the island being the release considered in the base scenario, greater effort was placed on model development in this area. The biosphere model will therefore require optimisation to allow both areas to be assessed in the same level of detail. The most conservative canister locations, in terms of release to the biosphere, will be selected for assessment in BSA-2020.

A further comment received from STUK was that greater transparency is required in relation to the selection of biosphere scenarios and their linkage to geosphere scenarios. Different nomenclature was presented between biosphere and geosphere scenarios in the assessment, leading to confusion. Posiva is therefore working to unify the names of the scenarios between the different aspects of the facility assessment.

It was recognised in the feedback received that Posiva had developed a state of the art model. However, the reporting of the model was not sufficient to allow results to be reproduced. The models therefore need to be more transparent and simpler to use. For the next assessment, Posiva aims to have an optimised model, and will also apply the reference biosphere approach. By applying this latter approach it is hoped that calculations will be reproducible.

Complementary considerations included in the license submission were considered highly relevant, but greater detail on the use of reference areas was considered necessary. Land uplift is an important process for the disposal area, giving rise to major lakes in the future. With such lakes currently being absent from Olkiluoto Island, reference lakes have been researched. There has been quite detailed justification for how the reference area was selected. However, this was written in a Finnish language background report and English reviewers of the license submission were not therefore able to consider the information within the report. The justification reports will be written in English in the next stage of reporting. A probabilistic model of landscape evolution will also be considered and linkage between future lakes and the selected reference lakes demonstrated.

The overall model for land uplift, based on a semi-empirical approach, has been accepted by STUK although some uncertainties have been recognised. Posiva will make some updates to the model for the BSA-2020 assessment, but no major changes are planned.

The next assessment will also use a 500 year time step in biosphere modelling within an overall time window of 10,000 years. The use of the planned time step will negate the need to consider forest ages. Element pools and fluxes within ecosystems will be represented in Ecolego. The use of this approach should allow results to be readily reproduced. The overall structure of biosphere objects will remain the same as in BSA-2012.

The main new aspect to be considered in the BSA-2020 assessment will be the L/ILW repository that will be located at 180 m below ground and will give rise to new release locations to the biosphere. This repository will be integrated within the spent fuel repository safety case. The modelling of radionuclides in the biosphere will be the same in principle as for the spent fuel repository, but different radionuclides may need to be considered. Additional developments will be the use of a simplified tool to allow probabilistic evaluations to be undertaken, a new approach will be taken toward surface hydrology and the C-14 model will be updated. It is also intended that some comparison will be made between the non-human biota ellipsoid approach and voxel phantoms.

Discussion

The Posiva approach to assessment for BSA-2020 is aiming to produce an assessment that exceeds regulatory expectations. This will be achieved by optimising the BSA-2012 approach rather than adding more detail. The Finnish repository programme is at a much more advanced stage than many other programmes internationally. As programmes progress towards implementation, the level of detail in assessment tools will improve and this is likely to be the case for other national programmes; the detail and complexity of the safety case will necessarily change as a safety case progresses from generic through to site specific and the different stages of licensing.

In the comparison of voxel phantoms and ellipsoid approaches to biota dose assessments, it is intended that use will be made of the output from the IAEA MODARIA programme rather than undertaking work directly with voxel phantoms.

In updating the C-14 model, it is intended that use will be made of the output from the various BIOPROTA C-14 work programmes. Additional sources of information, such as SKB reports, will also be utilised.

2.5 WHAT'S HAPPENING AT SKB – THE NEXT DECADES?

Ulrik Kautsky presented an overview of the SKB research and development programme, including a resumé of the last three years scope and the programme for the next three plus three years.

The Swedish regulator, SSM, has requested a change in SKB reporting. This will be taken into account in the research plan submission that is due in September 2016 (in Swedish with an English translation in October or November).

An application, SR-Site, to build a repository for high level radioactive waste was submitted to SSM in March 2010 and SKB is currently working to address questions that have arisen from SSM's review of the submission and those arising from other authorities and the Environmental Court. It is hoped that a first response on the application will be received from SSM in the autumn with a decision from the court potentially being given in 2017.

SKB is the organisation responsible for all radioactive waste in Sweden. Spent nuclear fuel is currently stored until a repository for disposal is available. A repository for short-lived low-level radioactive waste, SFR, is operational, although a submission, SR-PSU, was made to SSM in 2014 for an extension to the facility. The planned extension to the facility is to allow for the disposal of future operational waste arisings and some decommissioning wastes. It is intended that intermediate-level waste will be disposed of in a separate facility, SFL. Reports in support of the license submissions for SR-Site, including the biosphere synthesis reporting, and SR-PSU are available from the SKB website.

The dose assessment for the SR-PSU submission included a range of scenarios, including use of the natural system by people in a hunter-gatherer lifestyle, use of small garden plots for growing vegetables, and larger-scale agricultural pathways, including drainage of a mire for agricultural use. The productivity of areas provides the basis for determining the areas of land required to sustain people.

For the SR-PSU assessment, the C-14 assessment model was extended from that used in SR-Site to contain organic sediment and soil compartments. Atmospheric exchange was also incorporated.

The results of the dose assessment were close to regulatory risk/dose standards and were higher than for the spent fuel repository. Three radionuclides (C-14, Mo-93 and Ni-59) dominate at different times of assessment. The C-14 landscape dose factor is sensitive to plant water uptake and the rate of soil degassing and much can be learnt from studying natural processes. The role of methane needs to be looked at more closely, particularly to determine whether it is metabolised and the extent to which this occurs. The current approach for landscape objects is to assume that they are homogeneous, but SKB is now looking at heterogeneity within objects.

The SR-PSU reports are currently under review by SSM and the focus of SKB is now on a facility for intermediate level waste disposal. A concept study is currently being undertaken and a preliminary safety assessment is planned. It is not expected that an application for the facility will be made within the next 30 years.

Currently, intermediate waste is stored, but the content of drums is not fully known. Some of the drums show signs of deterioration and packages are therefore being redesigned to further ensure protection. In addition to radionuclides, it is likely that other pollutants such as mercury and some organic contaminants will be present in the wastes and consideration needs to be given as to how to address this mixed waste issue.

Laxemar is being used as a preliminary site for the basis of a generic assessment with biosphere objects being defined across that area. The site is currently terrestrial so the consideration of transitions is not so complex as for the Forsmark site in the SR-PSU assessment and shoreline displacement is not such an important consideration. Mires are however important ecosystems, having the potential to be drained for agricultural purposes.

Based on previous assessments, it is realised that discharges will likely be in or close to rivers. The intermediate-level repository is likely to result in relatively high doses and the approach to modelling should therefore be as realistic as possible. Whilst it is considered, based on hydrology, that discharges will be to rivers, there is a need to be able to defend this position and to consider alternatives.

A coupled near-field to far-field model will be applied such that the discharge from the repository will be coupled to the recipient surface environment and allowing dispersion in time and space to be evaluated. The biosphere model is likely to be similar to that for the SFR facility, but some specific element considerations will be required. 3-D modelling of the landscape and Kd with Comsol and PHREEQC is ongoing to evaluate how sorption varies over time and space in a changing landscape and how shoreline displacement affects geochemistry. Future climate change is also required to be considered in detail, particularly the formation of taliks under colder climate conditions.

There is also a plan to revisit the assessments that have been done to date to consider what can justifiably be generalised and determine the important features and processes in the long-term that require site-specific consideration. All major conservatisms will be identified and reviewed with a view to reducing conservatism and justifying the approaches.

Discussion

Food consumption in relation to climate is addressed by first modelling the landscape to evaluate what can be produced and then looking at what people can utilise at different times. For example, vegetable crops would not be produced under permafrost conditions. Consideration has not yet been given to the implications of warmer climate conditions on food production and consumption, since the major impact on food production will be associated with cooler climates. A warmer climate would slightly increase productivity from that at present due to a longer growing season. Greater precipitation would also be associated with a warmer climate however, which would result in a greater dilution of radionuclides entering the surface environment.

2.6 DEVELOPMENT OF THE NUMO SAFETY CASE – BIOSPHERE ASSESSMENT

Sanae Shibutani presented.

NUMO is due to submit a generic safety case report in 2016. The last assessment report, H12, was published by JNC (currently JAEA) in 1999. The report aimed to demonstrate the feasibility for the safe and technically reliable disposal of radioactive waste, based on a generic study approach. On the basis of the H12 report, the Final Disposal Act for implementing geological disposal of high-level waste came into force with NUMO being established in 2000. NUMO then proceeded to initiate the siting process, calling for volunteer municipalities, in 2002. In 2007, intermediate-level waste (TRU waste) was included as a waste stream requiring disposal. To date, no volunteer municipality has been selected. As such, in April 2014, a Strategic Energy Plan was developed that allows the Government to promote site-selection by suggesting locations that are scientifically considered to be more suitable for geological disposal of radioactive wastes.

The site selection process will encompass three main stages. The municipalities (volunteer or Government proposed) will be investigated through literature survey against selection criteria. Those sites passing to the next stage will then be subject to preliminary investigation, including geophysical surveying and borehole drilling. Those then passing to the next stage, relative to further screening criteria, would then be subject to detailed investigations, leading to the selection of a preferred site. At each stage, hearings would be held between the government, governors and mayors. The plan is for a site to be selected in the late 2030's.

The public are somewhat sceptical on the feasibility of achieving safe disposal, which has not been helped by the recent nuclear accident at Fukushima. Achieving a more convincing argument for safety is therefore important. NUMO therefore aims to integrate the required technology to demonstrate safety and feasibility based on the latest knowledge and a generic safety case is therefore being developed in 2015. The concept for the safety case is being taken from the NEA/OECD and the IAEA.

The 2015 safety case is being planned so that the basic structure of the safety case will be applicable to any site following selection. To demonstrate feasibility, geological and hydrological models for the type of host rock to be selected are to be developed by interpreting and synthesising data from the latest geoscience information in Japan since the H12 report. The repository design and safety assessment are to be based on latest scientific and technical knowledge.

In line with the Final Disposal Act, a multi-barrier system is being considered, consisting of a mined geological repository with a required scale being based on 40,000 canisters of vitrified waste and 19,000 m^3 of TRU waste in various forms. The repository concept will include a description of the long-term safety of the disposal system and the safety functions of both the natural and engineered barriers. Procedures for construction, operation and closure will also be documented. The long-term safety and operational safety plus other aspects such as economics will be used to evaluate the safety case.

The biosphere assessment will be contained within chapter 7 of the main safety case report. Key statements that will be included are that the assessment is based on an understanding of the geological environment and repository design and a risk-informed approach will be introduced that includes a range of scenarios classified as base scenario, less-likely scenarios and very unlikely scenarios. Human intrusion scenarios will also be included. Each of the scenarios will be developed with consideration of the probability of occurrence during the evaluation period using FEP and safety function based approaches. Safety standards have not yet been defined in Japan so evaluation will be based on international standards.

Safety criteria will be applied to scenarios, as follows:

- Likely scenario: probability of occurrence of 1 and a target dose of 10 µSv/y.
- Less likely scenario: demonstrate effects are limited, taking account of parameter variation, and a dose criterion of 300 µSv/y.
- Very unlikely scenarios: used to cover very unlikely scenarios such as very large earthquakes or volcanic eruptions. Safety criteria of 20-100 mSv or 1-100 mSv/y would be applied depending on the probability of the scenarios.
- Human intrusion scenario: safety criteria as recommended in ICRP Publication 81 of 1-20 mSv/y to those around the site and 20-100 mSv to the intruder would be assigned.

The timescale for the assessment is 1 million years post-closure, but this is beyond the time for which a meaningful quantitative assessment can be undertaken. As such, qualitative assessment and/or complimentary indicators will be used to support the demonstration of safety in the longer term.

Some of the key issues associated with the approach are demonstrating a practical methodology and procedures that can be applied to future candidate sites, which requires the method to be realistic and detailed in representing specific features of a repository system and its evolution over time. The scenario development method is particularly important in ensuring that comprehensive and consistent sets of scenarios are developed and their probabilities of occurrence evaluated. The basic strategy for the safety assessment and the handling of uncertainties is being developed. Since there is no site to focus the assessment on, possible site processes are being considered through application of international FEP lists such as that of the NEA, supplemented by particular events of relevance to Japan. Storyboards are being used to bring together diverse multi-disciplinary input in a user-friendly manner and are a natural way to represent the evolution of the system over time.

Models for radionuclide migration are based on transport in groundwater, assuming a granite host rock with fractures. The fractures are the basis for groundwater transport of radionuclides to the surface environment. The basic strategy for the safety case is to apply realistic models and data for a generic site, whilst taking uncertainty into account. Mean, average and modal values will used when constructing parameter data sets and variable models will be developed with parameter datasets that allow environmental conditions to be considered. The overall objectives of the 2015 assessment will be to confirm the methods and simulation tools for the biosphere assessment, develop the latest parameter datasets for various conditions and confirm the effects of uncertainties in models and parameter values.

A stylised approach to biosphere assessment will be applied, based on BIOMASS, using the AMBER modelling code. The effect of each parameter on the total assessment will be considered with the range of parameters being updated from that within the H12 assessment. The reference case will consider an inland site with a repository constructed at a depth of 300 m. The interface between the geosphere and the biosphere will be a river system. Variable cases will be identified by considering the landscape under different climate conditions. Radionuclide migration processes will be considered for each. Different geosphere-biosphere interfaces will also be considered in the variable cases, including well and seabed interfaces. Whilst the overall processes are likely to be similar, dilution will vary. For example, the difference between well and river dilution is some 3 to 4 orders of magnitude.

Within the work plan for 2015, parameters are to be set for the seabed model for which marine fishermen are the main exposure group. The datasets for Kd and transfer parameters will also be updated. A first draft of the main report is due to be completed by March 2015. This report is to give the main analytical results. A second draft is due in October 2015. An advisory group and international review team will be employed to comment on the draft with comments being used to refine the report with a final report due to be submitted in March 2016. An English translation will then be published. The plan represents a tight schedule.

Discussion

It was noted that SCK·CEN currently has a member of staff working on the measurement of Kd and transfer factors in Japanese soils as the basis for parameterising a caesium model. This could provide a potential collaboration opportunity for the exchange of information and data.

The Finnish disposal site is coastal, but marine fishermen have not been considered as an exposure group due to the large dilution offered by sea water and the fact that drinking water is the primary exposure pathway. In Japan however, the GBI release point may be directly to the marine environment and so those living in the coastal area and consuming local fish may be the most exposed group. Since the 2015 report is designed to be transparently relevant for the public, it is necessary for this pathway to be included due to the importance of marine fish in the Japanese diet. Fishermen are also considered as an exposure group in the UK by Low Level Waste Repository Ltd where exposure pathways include consumption of local sea foods and exposure to contaminated fishing gear.

A distinction should be made between probability in a year and probability over a longer period. There may be a very low probability of an event occurring within a year, but over 10,000 years or more the event may be more likely. Whilst it is not possible to quantify probabilities over time precisely, the distinction should be considered and noted in discussions.

The current status with regard to nuclear power in Japan is that there are around 50 nuclear power plants that were shut down after the Fukushima accident. These plants have been awaiting permission to restart power generation. (Since the meeting, re-start of nuclear power generation has commenced).

2.7 ASSESSING THE NON-RADIOLOGICAL HAZARD FOR A CANADIAN USED FUEL REPOSITORY WITH COPPER CONTAINERS

Neale Hunt presented.

No site has been selected in Canada for the disposal of high-level radioactive waste. A willing and informed host community is being sought. Initially 22 communities were identified, but the number has now reduced to 9 as a result of the ongoing siting process. Both crystalline and sedimentary rocks have the potential to be selected based on these community sites and two safety cases have therefore been developed, each focussing on one of these host geologies in a site-generic context. The focus of these assessments is on radiological safety with a 1 million year assessment adopted as the timescale of interest, based on the time required for the used fuel to decay to essentially the same level as natural uranium. However, it is recognised that many other hazardous materials would be associated with the repository that do not decay, such as copper and uranium. The non-radiological hazards are therefore also being investigated.

Regulatory requirements have been published in CNSC Regulatory Guide G-320 on assessing the long-term safety of radioactive waste management (available from the CNSC website). This stipulates that the applicant is required to propose justified and scientifically defensible criteria for the assessment, including criteria for the protection of people and the environment from hazardous substances. Consistent with this requirement, NWMO has proposed interim acceptance criteria. The criteria were derived on the basis of a tiered approach. Primary references were used for various environmental media (surface water, groundwater, soils etc.), such as Canadian federal and provincial government guideline concentrations. Secondary references published by reputable institutions that have been peer reviewed were also used. The intention was to be cautiously realistic, without being overly conservative. Minimum value tables were generated from which tables of interim acceptance criteria were developed. The difference between the two tables was that higher values could be adopted in the latter where this was justifiable. Exceedance of the interim acceptance criteria does not necessarily indicate an unacceptable risk; some values are based on background measurements. Where there is an exceedance, the approach would be to consider the degree of conservatism and to refine the assessment. Further information is available on the derivation of acceptance criteria in NWMO report TR-2015-03, available from the NWMO website.

A number of issues were encountered in deriving the acceptance criteria such as the approach that should be taken for elements for which no data could be identified and which chemical compounds should be considered (for example, C as CO_2 is much less hazardous than C as CN). Furthermore, background concentrations of some elements / compounds at a site may already be high.

In addressing the elements to be considered, some exclusions were justified such as those elements that are very common and essential to life, inert gases and actinides. The latter were excluded since they pose a more radiotoxic risk than chemotoxic risk. Transactinides were also excluded due to their short half-life. Whilst a number of elements were excluded, a number remained for which no data could be found. Further exclusions may be possible, for example where the concentrations in the waste form were below the natural abundance in environmental media, but it is unlikely that all elements for which data are lacking could be justifiably excluded.

In terms of the chemical compounds that should be considered, some data were available from primary references and these were screened for relevance to a spent fuel repository. For those compounds of interest, criteria were selected on the basis of the lowest elemental or relevant compound value.

With the assessment being site-generic, a background concentration of zero was assumed. Consideration needs to be given to the approach that should be taken when a site has been selected however since, if background concentrations are taken into account, exceedance of acceptance criteria may occur. It is anticipated that regulatory involvement will be required to determine the most appropriate and acceptable approach to this issue.

For the assessment, the same tools and methods were used to evaluate chemical hazards as for the radiological assessment, including an initial screening to identify the contaminants of concern. A range of different scenarios was considered. The normal evolution scenario assumed that 1 in 5000 containers has an undetected defect, with reference cases being used to look at different variations around this scenario such as high diffusion rates. A limiting scenario of all containers failing was also evaluated. In all cases the receptor was assumed to be a self-sufficient farming family deriving drinking water from a deep well located in the worst location. Assessment results were compared in proportion to the assessment criteria with a quotient greater than 1 indicating an exceedance.

For the crystalline repository case, mercury, lead and cadmium exceeded the safety criteria (risk quotients of 3.3, 1.6 and 1.1, respectively). Risk quotients were all less than 1 for the sedimentary repository case. Some exceedances were recorded under the all cylinders fail scenario, but these results could be argued out on the basis that such a case is unrealistic.

Variant scenarios were also considered for copper and uranium in the canisters, in which a solubility limited concentration was used as the source term, with all copper or uranium transported to the surface being assumed to enter a well. Neither copper nor uranium was found to be an issue.

Complementary indicators were also considered. For example, natural element transport rates to the biosphere can be estimated using the elemental composition of granitic Canadian Shield crystalline rocks and other sedimentary formations and the erosion rates over long periods. Relative to the all canisters fail scenario, the erosion transport was greater for all elements considered, giving additional confidence that the repository will not have a significant effect on people or the environment. A further complementary indicator assessment may be undertaken by NWMO in the future to compare results against concentrations in lakes and rivers.

Assessing the non-radiological hazards associated with a radioactive waste repository therefore involves similar activities as for evaluating the radiological hazard. The main difficulty however is in defining acceptance criteria for the range of hazardous substances that may be present. This may present an opportunity for a collaborative project within BIOPROTA to consider what has been done internationally to address non-radiological hazards, identify references that are available on acceptance criteria and consider approaches to addressing situations where those criteria are exceeded.

Discussion

The Canadian regulator expects calculations to be continued until the peak release to the surface environment is observed. For sedimentary rock formations this peak will occur at around 15 million years or 8 million years under a high diffusion case.

The interim acceptance criteria have not yet been accepted by the regulator. Some comments have been received and most have been addressed although there remain some open issues. The criteria have been set on the assumption that people in the future should be protected to the same extent as people today.

There will be community consultation on the assessments performed, but presentations will focus on the radiological hazards since these are the key focus interests of members of the public. A balance is required between science and people’s values. Each volunteer community has a community liaison committee that is comprised of 6 to 7 volunteers from the community. NWMO provides information to these committees and provides advice on communication with the rest of the community. All meetings held are open to members of the public. Before any site can be selected there must be a demonstrable majority in favour of construction within a community. Not all sites are in close proximity to communities however. Some sites are also disputed territories and Aboriginals will also be consulted.

Hazardous materials associated with radioactive waste disposal do not decay. Comparison with natural fluxes of elements and compounds is therefore considered useful in providing context to the risks posed. Radionuclide hazards could also be presented in terms of natural fluxes and this approach could be taken forward if the methodology is accepted for hazardous materials. There may also be a need to consider hazards associated with organic materials such as organic forms of mercury. Whilst this is not an issue for spent nuclear fuel that does not contain any organic material, it may be relevant for low- and intermediate-level waste. Whilst the hazards associated with non-radioactive materials present in wastes may be greater than the radiological hazards, it is often the case that they receive less attention from both regulators and operators.

2.8 STATUS OF SWISS SITE SELECTION PROCESS.

Andreas Poller presented.

It is a legal requirement in Switzerland that all categories of radioactive waste are to be disposed of in deep geological repositories, no surface or near-surface facilities are permitted. Two repositories are therefore planned – a high-level waste repository for which the assessment time frame will be 1 million years and a repository for low- and intermediate-level waste for which an assessment timeframe of 100,000 years will apply. There is also an option for a combined facility to be constructed. For a high-level waste repository, horizontal placement of canisters with a bentonite backfill is planned at a depth of up to 700 m in a clay host rock (Figure 2-9). A surface facility would be constructed for waste encapsulation and other disposal preparations. A ramp and/or shaft(s) would provide access to the disposal area.

There is a stepwise process for selecting a disposal site that is documented in a Sectoral Plan. This plan details the rules and criteria for site selection. Stakeholders are also defined and the roles of the different stakeholders are assigned. The priority is given to post-closure safety and selecting the safest site rather than one that is considered safe enough. Safety relates to the technical feasibility, ability to obtain reliable geological information, provision of good host rock properties and the long-term stability of that host rock. The siting process began in 2008 and is ongoing.

There are three stages to the siting process. Stage 1 involves the selection of siting regions on the basis of their suitability in terms of geology, based on existing information. Stage 2 involves identifying, for each possible siting location, an area where a surface facility could be placed. This process involves consultation with the local communities and takes into account economics and transportation. Furthermore, siting regions with clear disadvantages are placed in reserve. Stage 3 then involves the selection of a site for each repository type, based on safety considerations, with site investigations being undertaken in support of this. Once a site has been selected for each repository type, a license submission will be prepared.

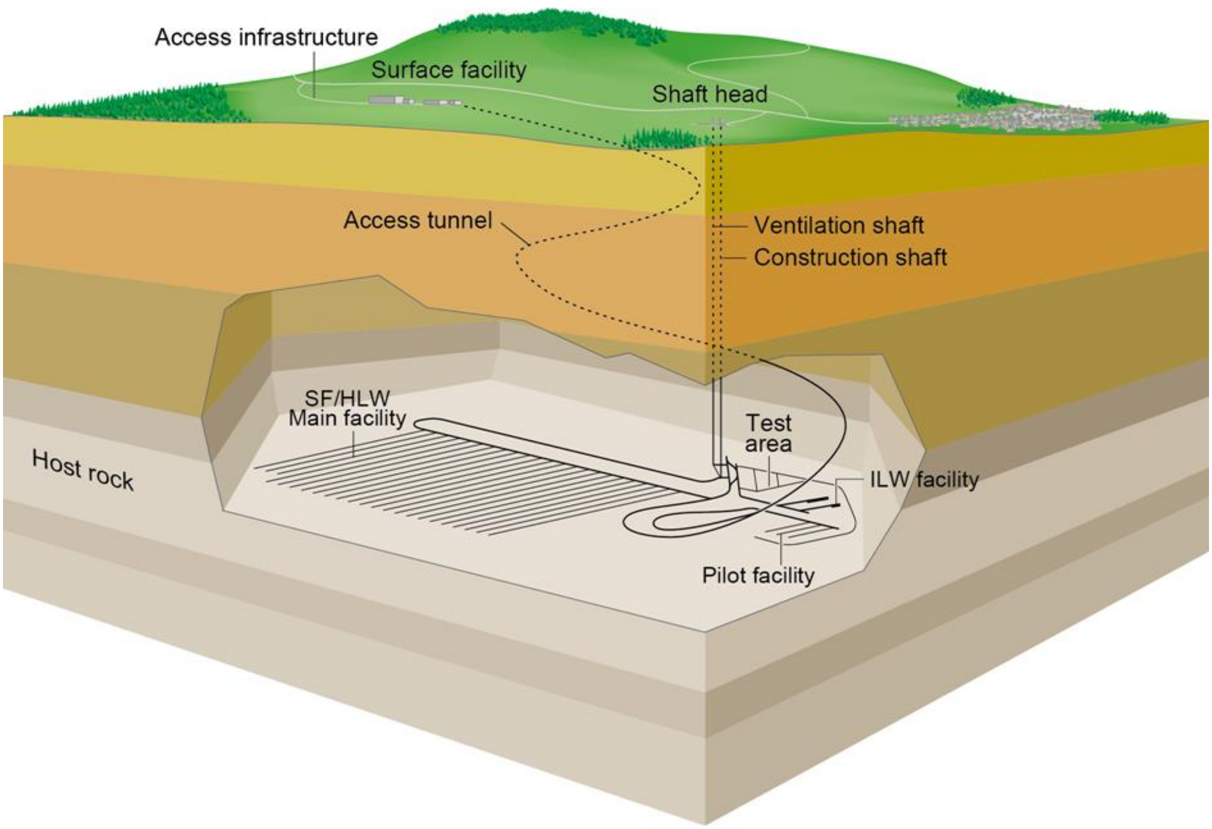


Figure 2-9. Example design for a high-level waste repository.

Stage 1 has been completed with six locations being identified in total (Figure 2-10). The siting proposals have been evaluated and were accepted by the Federal Council in 2011. Siting locations for surface facilities have been proposed by Nagra and discussed regionally as required under stage 2 of the siting process. Views have been expressed by communities in each of the proposed regions with interest in operational safety rather than long-term safety being paramount since the public rely on the implementer and the regulators to ensure the long-term safety of a facility.

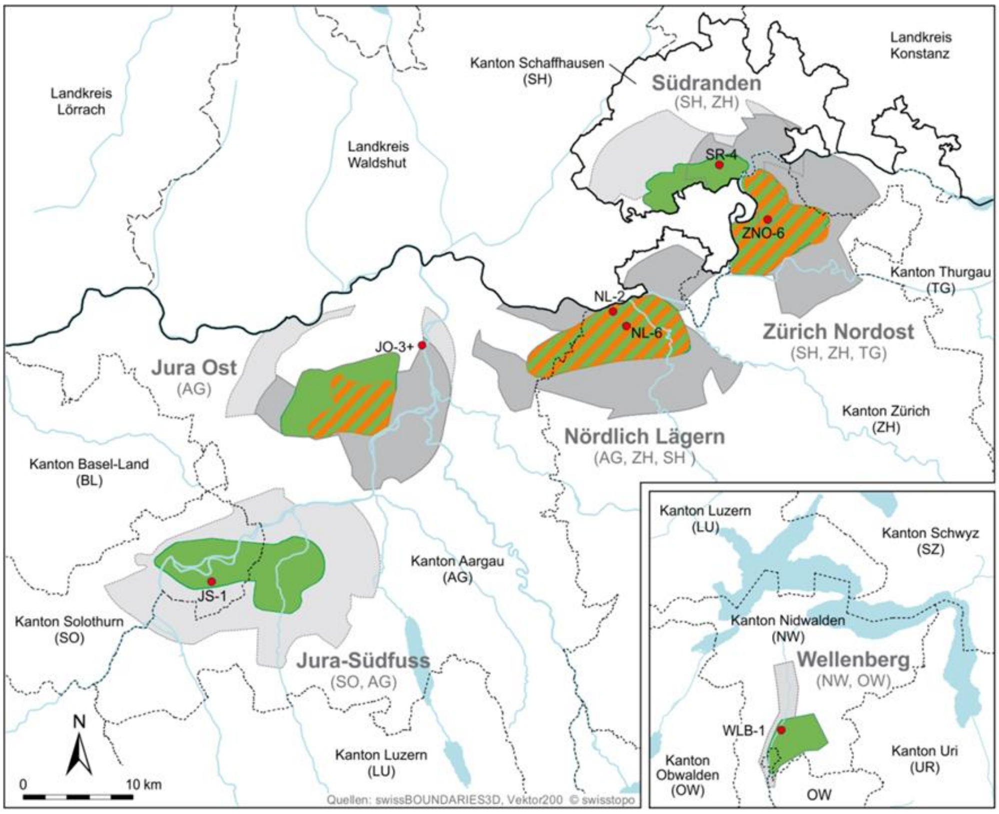


Figure 2-10. Stage 1 siting locations for high-level waste (orange) and low/intermediate level waste (green) repositories with surface facility locations indicated (red dots).

In January 2015, a report detailing a safety related comparison for each siting region was submitted that resulted in two siting regions being proposed for each repository type with both Zurich Nordost and Jura Ost being selected for both repository types. Whilst the same regions have been proposed, the most promising locations for each repository type within those regions differ, due to differences in the long-term safety requirements for each repository type and area required.

There are a number of regulatory requirements on biosphere modelling for stage 2 of the siting process. Dose calculations undertaken to narrow down the number of potential siting regions are required to be based on a reference scenario for repository evolution that assumes radionuclide release with deep groundwater. Climate variation is also to be analysed, including at a minimum, consideration of the current climate, a warmer and drier climate and an ice-age climate. Moreover, detailed investigation of landscape evolution is to be carried out. For each siting region, hydrogeological conditions are to be analysed and modelled in order to identify discharge areas and the potentially most exposed group, with biosphere modelling then being carried out at a site-specific level and taking account of local morphologies and climate conditions.

Nagra has published a series of reports on the stage 2 assessment. The approach to addressing the long-term impact of climate has been focussed on effects on the geosphere rather than the biosphere (report NTB 14-02, volume 3) and analysis and modelling of the hydrogeological situation at each site and identification of potential discharge areas has been undertaken (report NTB 14-02, volume 5). The hydrogeological situation at each potential discharge area has also been evaluated and reported in report NAB 13-75. There are a number of uncertainties associated with geomorphological and climatic evolution (in terms of radiological impact) that were judged to be greater than present-day and expected future variability between potentially affected areas. As such, site-specific models were not considered appropriate for thee safety-related comparison and a generic reference biosphere system, relevant to all geological siting regions, was adopted. Climate variations were investigated using this reference biosphere. Site biosphere models were nonetheless developed for potentially affected areas that reflect the differences in current geomorphology, hydrogeological and climatic conditions between the candidate sites. These models were used to illustrate the effects of present-day variability between the sites and to evaluate the safety relevance of these differences. Transient biosphere models were not employed. Rather, steady state biosphere dose conversion factors were used to convert geosphere releases to dose rates.

The main biosphere modelling activities that were associated with the stage 2 process were:

- Re-implementation and update of the earlier TAME model in the SwiBAC model that makes use of the compartmental model AMBER;
- Refinement of the C-14 model and implementation in AMBER to interface with the SwiBAC model for calculation of radiological consequences; and
- Use of updated generic biosphere parameters from an international review.

All of the reports arising from stage 2 of the siting process are available from the Nagra website, with the majority of biosphere modelling reports being available in English. Available reports are as follows:

- Outcome of SGT Stage 2
    - NTB 14-01 (Main report, German)
    - NTB 14-02 (Geoscientific basis, several volumes, German)
    - NTB 14-03 (Dose calculations, German)
- Biosphere modelling in SGT Stage 2
    - NTB 14-09, Chapter 4 (Overview of biosphere modelling, English)
    - NAB 13-04 (Main report on biosphere modelling, German)
    - NAB 12-27 (SwiBAC 1.2 model definition, English)
    - NAB 12-26 (Nagra C-14 model v.3, English)
    - NAB 13-49 (Review of generic parameters, English)

2.9 WASTE MANAGEMENT IN COMPARISON – MAIN CONCLUSIONS

Markus Hugi presented.

A project has been undertaken to consider the issue of the management situation in Switzerland for radioactive and non-radioactive wastes and to consider whether there is the possibility to learn from management strategies for non-radioactive waste streams, and apply this learning to radioactive waste management. Such learning was intended to help prevent excessive spending with regard to safety barriers without giving due regard to waste forms and packaging and whether these can be improved to reduce disposal facility engineering. The programme was undertaken within the Radioactive Waste research programme of the Swiss Federal Working Group for the Disposal of Radioactive Waste by a collaborative team of experts from various federal offices and the commission for nuclear safety. The project was coordinated by ENSI.

The project addressed both the strategic and scientific-technical considerations regarding the management of radioactive and non-radioactive wastes with the objectives to:

- undertake a systematic and comparative analysis of the current practice for both waste categories; and
- examine whether relevant principles and regulations of the Swiss Environmental Act are properly accounted for in the legislation for the management of radioactive waste.

There has been an ongoing debate in Switzerland over the last 20 years between various stakeholders on regulatory inconsistencies regarding the permitted organic content of radioactive and non-radioactive wastes. The Environment Act calls for the incineration of organic waste and sets maximum quantities of organic material within waste (3 to 5 % by weight) that can be sent for underground disposal. The Nuclear Energy Act however calls for the minimisation of organic content but does not provide quantitative constraints. There are further inconsistencies in that the Environment Act calls for the recovery and re-use of elementary metals whereas such metals are used in radioactive waste disposal.

The report of the project was published in February 2015. Differences in the legislation regime for the different waste types were justified. For example, non-radioactive waste disposal is addressed by the Environment Act. The Act considers near-surface disposal of large volumes of wastes that are neither re-usable nor combustible. Radioactive wastes however are relatively small in quantity and disposal aims to minimise risks and allow for radioactive decay. The geological disposal of these wastes is only permissible after authorised conditioning of waste packaging and provision of appropriate package-specific documentation. Diminishing risk potential is not a feature relevant to non-radioactive hazardous wastes.

Both commonalities and differences were identified. For example, dilution of wastes is prohibited in both cases, there is a requirement to minimise wastes and the polluter-pays principle applies. There are also real differences in relation to requirements for the immediate conditioning of wastes and limitations on organic content of disposed wastes.

One of the issues that was to be addressed was whether or not the technical ordnance for wastes should apply to radioactive wastes. The conclusion was that it should not apply. The ordnance relates to conventional wastes from households and small businesses to allow non-recyclable materials to be disposed of with an aim to reduce volumes of waste as much as practicable.

Organic material in wastes can lead to gas production in the presence of microbes that could give rise to damage to safety barriers. The complexing nature of organics could also lead to the increased mobility of radionuclides and to enhanced cement degradation. The requirement to minimise organic material associated with radioactive waste is therefore safety oriented. Metallic radioactive waste can also be an issue with gas production occurring as a result of anaerobic corrosion. There is therefore a requirement to minimise metallic wastes in addition to organic materials. Waste streams affected by these requirements include L/ILW categorised resins, concentrates and mixed (organic) operational wastes and metallic waste from decommissioning of nuclear power plants and large research facilities and metal containers for spent fuel and high level waste designed according to Nagra's multi-barrier system. The current design for such containers involves forged steel. The study has shown that it is the metallic wastes that give rise to the greatest concern from gas production. The rate at which gas production occurs is also an important consideration. A study by Nagra has demonstrated that organic components present in waste would lead to extended rather than rapid production of gas. The host rock is then an important feature, governing whether generated gases can be gradually released or whether build-up may occur that could give rise to damage.

Most of the waste arising from decommissioning activities is associated with research facilities, accounting for 25% of waste as compared with 20% from the nuclear power plants. Disposal feasibility has been demonstrated by Nagra, reviewed by ENSI and by the Federal Council for L/ILW and HLW. The feasibility and safety assessment took into account the consequences of metallic and organic material being present in the disposal facilities. All wastes destined for disposal must be certified and a waste producer is required to apply for a permit to produce a particular waste package according to defined methods. Acceptability for disposal is evaluated on the basis of individual waste types by the implementer and is reviewed by the safety authority.

Under Article 4 of the Nuclear Energy Act on the principles governing the use of nuclear energy, it is required that humans and the environment must be protected from ionising radiation and precautionary measures must be taken in accordance with the state of the art in science and technology where contributing to an additional reduction in risk. This requirement has been incorporated into guidelines issued by ENSI, calling for optimisation for operational and long-term safety and consideration of alternative waste treatment options. An example of an alternative waste treatment process would be the use of pyrolysis to solidify organic L/ILW wastes such as ion-exchange resins or the smelting of metallic wastes to allow removal of some radioactive material in the slag. This has the advantage of reducing the surface to mass ratio significantly and thus reducing gas production rates. For higher level wastes and spent fuel, copper could be used in place of forged steel to avoid corrosion or ceramic composites could be used as a coating to steel containers. Alternatively, super containers could be used that provide additional technical barriers such as cement.

Revisions to the radiological protection legislation are planned, to take account of updated recommendations and standards from the ICRP and IAEA that will be incorporated in terms of revised clearance levels. This may affect estimates of future volumes of waste arisings, for example, for metallic decommissioning wastes.

Waste producers are being asked, as part of the recommendations from the project, to undertake a sound evaluation and safety-orientated assessment of the state of the art technical processes to prevent and reduce organic substances and metallic components in L/ILW and to undertake assessment of alternative disposal containers for spent fuel and vitrified HLW. Results of the corresponding investigations are to be documented by the waste producers in the 2016 waste management programme.

2.10 LLWR ENVIRONMENT SAFETY CASE UPDATE

Alessandro Proverbio presented.

The Low Level Waste Repository is on a working site that, prior to its current use, was a Royal Ordnance Factory that produced TNT. In 1957 the site was granted permission for radioactive waste disposal. From 1959 to 1995, disposal at the site involved tipping of LLW into clay-lined trenches. In 1988 the disposal concept was revised and the first operational vault (vault 8) was commissioned. In 1995 a compaction facility was commissioned at Sellafield and a grouting facility became operational at LLWR. At the present time, wastes to be emplaced in Vault 8 are grouted into steel ISO-freight containers Vault 9 became operational for storage only in 2010. The disposal site therefore consists of wastes disposed of according to two disposal concepts – trenches and vaults. In 2011, the position at the site was that there were 7 trenches with an interim cap, Vault 8 was almost full with vault 9 being used for storage. In order to continue disposal of LLW at the site, further development was required to extend capacity, which required submission of a permit application for waste disposal, supported by an Environmental Safety Case (ESC). A planning application to Cumbria County Council would also be required for construction of additional vaults.

An ESC was submitted to the Environment Agency in 2011 that was categorised as adequate two years later, following review. In 2013, the ESC was used in support of a revised permit application. The Environment Agency are now consulting on their proposed decision on the application. A final decision is expected on the application by the end of 2015.

The permit application is to extend the capacity of the site to allow for disposal of LLW expected from the UK Radiological Inventory until 2080. This would involve changing the purpose of Vault 9 from storage to disposal and including additional vaults.

Whilst the initial planning application was submitted for constructing Vaults 9 to 14, this application was withdrawn following discussion and a revised application has been submitted for Vault 9 and Vault 10. This will provide capacity for disposal until the late 2020's.

The 2011 ESC took three years to produce at a cost of £8 million. It was supported by 100 key underpinning reports (topic reports and supporting documents) that equated to 85 man-years of work. The documents are available at http://llwrsite.com/national-repository/key-activities/esc/esc-documentation/. Around 40 liaison meetings were held with the Environment Agency during production. Regular consultation with the Environment Agency was very useful in making a successful case.

There were three key underpinning models employed characterising near-field, geology and hydrogeology. The facility is in close proximity to a coast that is subject to erosion. A detailed 3-D geology model was therefore employed that was used to provide input data to the 3-D hydrogeology model, and considered both upper and regional groundwater flow. The hydrogeology model was developed on the basis of the local geology as characterised from borehole observations. In the near-field, trenches and vaults were represented by inter-connected compartments and radionuclide transport was considered in relation to transport in water and gas generation. Exposure pathways considered included gas (C-14 and radon) generation, use of a contaminated well, release to the marine environment, exposure relative to a stream and estuary, human intrusion and coastal erosion.

For the well pathway, both radiological and non-radiological contaminants, transported in groundwater, were considered. The plume area was evaluated and risk calculated by integrating concentrations across the relevant area of the plume. Concentrations of non-radiological contaminants were evaluated relative to appropriate groundwater standards at the compliance point. Both probabilistic and deterministic models were employed for radioactive contaminants, but for non-radioactive contaminants only deterministic models were employed.

For the transport of contaminants in groundwater to the marine environment, radioactive risks were evaluated. This was also the case for the stream and estuary release pathway, with risks deemed to be very low. For the gas pathway, the long-term impacts of C-14 release via food ingestion were considered and the inhalation of radon by inhabitants of a house with a basement penetrating the cap was assessed. A revised assessment model for C-14 has been developed since the ESC that draws upon information gained through the BIOPROTA C-14 work programmes to improve the representation of C-14 behaviour in soils and uptake into plants.

A range of human intrusion scenarios were considered within the ESC, including housing development, smallholdings and local organised material recovery. Exposure pathways for these scenarios included the inhalation of gases or dust, ingestion and external irradiation. Risks were computed according to different areas of the site.

Coastal erosion is a key process requiring evaluation for the site. Erosion of the site will occur over a period of a few hundred to a few thousand years. Whilst there is uncertainty associated with the timescale, the fact that erosion of the site will occur is not uncertain. The assessment undertaken was required to demonstrate that, during the erosional process, the repository would remain safe in terms of exposure of potential exposure groups. The erosional process will involve undercutting leading to the exposure of waste in the cliff and on the beach. Exposure groups included recreational users of the coast, occupational user of the local beach and high-rate local seafood consumers. The doses from each of these exposure pathways met regulatory requirements.

Following the review of the ESC, the Environment Agency established an issues resolution process that involves three categories of issue resolution form:

- Regulatory issues – the most significant issues.
- Regulatory observations – significant issues.
- Technical queries – simple questions.

A total of 72 issue resolution forms were received in response to the ESC, with LLWR responding to each of these. Forward issue forms were also provided that identify issues that are expected to be addressed as part of the ongoing work programme for the next major ESC, due to be submitted in 2021. Overall, 29 forward issues have been issued.

There is currently work ongoing to develop a live ESC that would become a tool to support site management The live ESC would be continuously updated to meet both site and assessment needs. Work is also ongoing to improve the inventory of legacy materials, including data relevant to non-radiological hazards. It is anticipated that there will be a need to further consider discrete items and active particles and to assess the disposal inventory in Vault 9 before undertaking any disposal activities.

There is continued interest in further collaboration on activities related to the integration of the geosphere and biosphere in assessments relevant to a LLW near surface facility.

Discussion

Public consultation has been ongoing throughout the ESC and permit application procedure. There is a good and constructive relationship between LLWR and the local community and concerns over radiological risks are low. In terms of coastal erosion, there is more a concern over the potential for waste to be present on beaches rather than in relation to any radiological impact. The disposal capacity of LLW in the facility is more likely to be restricted by compliance with Groundwater Daughter Directive than by radiological capacity issues. Many conventional waste disposal sites in the UK are in coastal locations and the erosion issue is not therefore restricted to the LLWR.

2.11 POINTS FROM THOSE UNABLE TO ATTEND

Graham Smith presented points provided by members of the BIOPROTA forum that were unable to attend the workshop. The following issues and interest areas were noted in responses received from BfS, Andra, ARAO and JGC:

- The different ways in which radionuclides can enter the biosphere and how these can be represented in the interface between the geosphere and biosphere continues to be an interest area for assessments.

- The possibility of disposal of radioactive wastes in salt deposits means that there is also interest in the implications of groundwater salinity on radionuclide behaviour. The salinity of groundwater would also determine its potential use by people.

- The appropriateness of using annual averages in long-term assessments is also an area where additional consideration could be given as some processes that are more seasonal may not be well represented by annual averages.

- Climate evolution and transitions between climate states, particularly when constant biospheres have previously been assumed. During climatic transitions radionuclides might be mobilised or immobilised in the biosphere. An understanding of what the most important climatic transitions to be considered in assessments and suitable approaches for modelling the consequences of such transitions would be beneficial.

- Behaviour of redox-sensitive radionuclides, particularly in relation to behaviour in moving between the geosphere and biosphere where rapid transitions in environmental conditions can occur.

- Further improvement of C-14 model capabilities, particularly in relation to representing organic and inorganic carbon in assessment models and through model-data inter-comparison exercises.

- Finally, many of those responding registered interest in the forward programme idea to undertake a review and update of the IAEA BIOMASS-6 methodology on reference biospheres.

3. BIOPROTA 2014-15 PROGRAMME UPDATE AND OTHER INTERNATIONAL PROGRAMMES

Work programmes progressed during the period since the last annual BIOPROTA meeting were presented. Information from other international programmes of relevance to long-term assessments were also summarised.

3.1 COMPARISON OF SAFETY AND ENVIRONMENTAL IMPACT ASSESSMENTS FOR DISPOSAL OF RADIOACTIVE WASTE AND HAZARDOUS WASTE

Graham Smith presented an overview of a workshop and associated report that was held in Asker, Norway in February 2015, hosted by NRPA. The workshop was on the comparison of safety and environmental impact assessments for disposal of radioactive and hazardous wastes and followed from a previous workshop that was held in May 2014.

Radioactive and hazardous waste disposal assessments have very different endpoints and timeframes of assessment are also variable. Whether or not the processes occurring, such as those relating to environmental behaviour, are assessed consistently is largely unknown. There are also wide ranging protection objectives and varying assumptions around land use planning. The workshop was therefore intended to provide a forum for discussion and comparison of assessments made of disposal of radioactive and hazardous waste, taking into account:

- Assessment methods for disposal of radioactive and hazardous waste;
- Comparison of assessment endpoints;
- Comparison of timeframes over which these endpoints are assessed;
- Key processes dominating the release and disposition of radionuclides and other pollutants within the environment, following disposal;
- Approaches to address the environmental change;
- Methods for assessing effects on human health and the environment (individual, population or ecosystem level);
- Assumptions for human behaviours and land use planning;
- Approaches to addressing uncertainties (precautionary principle, optimisation); and,
- Approaches to addressing low probability events that have high consequences.

The workshop was attended by a wide range of participants and a number of interesting presentations were given upon which discussions were held. Presentations relating to protection objectives and regulation were given on the following topics:

- Protection objectives, regulation and assessment methods.
- Methods for Safety Assessment of Geological Disposal Repositories.
- Regulation of Hazardous Waste.
- Radioactive Waste Management: A Norwegian Regulatory Perspective.

- Regulating the Radioactive and Non-Radioactive Components of Radioactive Waste for Disposal in England.
- Comparison of Criteria for protecting Human Health from Radiation and Chemical Hazards in the UK.
- Addressing Chemical Toxicity in Radioactive Waste.

In terms of assessments and scientific support, the following presentations were given:

- NORM Management in Conventional Hazardous Waste Disposals.
- NORM Waste Management in Norway.
- Post-disposal Assessment of Decommissioning Wastes.
- Scoping study of post-closure implications of hazardous substances present in a UK Geological Disposal Facility.
- An Ecosystem Approach to Integrating Radiation Protection with Environmental Protection.
- How to Assess Consistently (and Compare) Chemotoxicity and Radiotoxicity for Wildlife under Chronic Exposure Situations.
- Approach to Assessing the Impact of Non-Radiological Contaminants at the UK's Low Level Waste Repository.
- Remediation of TENORM residues: An Interdisciplinary Study for a Case in Hanover.
- Why Interim Storage Facilities in Japan are still Suspended: A Review.
- Multiple Stressors – Scientific Challenge.
- Comparison of Risk Assessment Frameworks for Radioactivity and Chemicals.

It is evident that there has been a separate development of assessment strategies for hazardous and radioactive wastes with hazardous waste management focussing on controlled release whereas for radionuclides the focus is more on containment to allow for radioactive decay. The timescales of assessment also vary considerably. For example, in the UK, hazardous waste assessments can be evaluated over a time period of up to 1,000 years (although shorter timescales are more commonly considered) whereas for radionuclides the timescales are considerably greater. These timescales are not considered commensurate with the risks posed in many cases.

The risk criteria that are available are not always consistent and, for many hazardous materials, criteria are unavailable. This makes it difficult to manage optimisation strategies when dealing with mixed waste streams. It was considered that the same level of protection should be offered across the different hazardous materials whether radioactive or not.

A facility is operational in Norway that offers safe treatment and disposal of hazardous wastes, including radioactivity associated with the NORM waste from the oil and gas industry. A site visit was incorporated into the workshop programme. The NOAH facility has a permit to dispose of 500,000 tonnes of inorganic hazardous waste and 500,000 tonnes of non-hazardous waste per year. In 2014, NORM waste accounted for around 1.4% of the total waste received to the island, of which 90% was Alum shale.

The core business for NOAH is the neutralisation of acid with alkali. Around 200,000 m^3 of sulphuric acid containing waste is received at the facility per year and this is neutralised with fly ash from the combustion of household and industrial waste not only from Norway, but from Sweden, Denmark and other European countries.

3.2 SCALES FOR POST-CLOSURE ASSESSMENT SCENARIOS (SPACE)

Karen Smith presented.

A draft report of the SPACE project on addressing spatial and temporal scales for people and wildlife in long-term safety assessments has been made available to project sponsors for comment. The project was driven by an increasing requirement to consider protection of the environment through dose assessments for non-human species in safety assessments for the disposal of radioactive waste. Whilst there is an increasing requirement for such assessments to be made, little guidance is currently available on the appropriate approach to undertaking assessments and assessments are commonly undertaken using data derived as input to human dose assessments. The spatial requirements of people and the wide diversity of species that may be of relevance to assessments are likely to vary considerably and use of an averaging scale appropriate for people may be overly conservative when applied to biota. The endpoints of assessment are also different with the focus for human dose assessments being on protection of an individual whereas for non-human species, protection of populations is the focus. By considering the different scales appropriate to biota dose assessments, assessment credibility may be improved that will benefit in terms of stakeholder dialogue on the risks associated with radioactive waste disposal and may also mitigate against the risks of unnecessary resources being spent on environmental protection through a misrepresentation of actual risk.

The main objectives of the SPACE project were:

- to advance understanding of assessment scales for averaging radionuclide activity concentrations relevant to populations of non-human populations; and
- to evaluate commensurability with current approaches for human spatial and temporal averaging.

The above objectives were set specifically in context of long-term safety assessments for radioactive waste repositories, with the scope being constrained to the terrestrial ecosystem under temperate climate conditions.

The project was undertaken in three stages:

1. Develop understanding of rationale behind scaling approaches for biota and human assessments through review of international guidance and approaches taken in long-term safety assessments undertaken to date.
2. Selection of ‘SPACE Representative Species’ and collation of supporting database of spatial and temporal parameters.
3. Evaluate commensurability of biota assessment scales with a ‘typical’ averaging scale for humans.

A range of representative species was selected for the project, broadly categorised according to the ICRP reference animals and plants, and assessment parameters were collated as input to the dose assessment methodology (the ERICA assessment tool). An investigation was then undertaken to ascertain whether appropriate groupings could be made of the selected species according to the spatial and temporal scales of each population through literature survey of population characteristics. All data gathered have been tabulated with references to allow original data sources to be identified. Data collated included home range, life span, distribution, territoriality and information on whether the species are migratory. Few data were available on the spatial ranges of populations with most data being presented for individuals. As such, a scaling approach was applied using a published method whereby a scaling factor of 40 is applied to an individual home range size to estimate the population range.

Based on the data collated, groupings of the representative species according to temporal (lifespan) and spatial (population range) characteristics were made. Temporal groupings ranged from less than 5 years to greater than 25 years. With the exception of the representative species pine tree, temporal scales were all short as compared with the long-term nature of assessments and multiple generations would occur within the time steps appropriate to long-term modelling. Modelling in shorter time steps, of the order that would be required for single generations, would entail significant extra resource and results would be difficult to defend on a robust scientific basis. As such, the temporal scale was not taken further forward.

For spatial scales, representative species were grouped according to the range categories illustrated in Figure 3-1.

SPACE reference group	Common name
Immobile	Fescue grass
	Fragile brittlegill fungus
	Glittering Wood-moss
	Scots pine
Small ($<0.5 km^2$)	Black garden ant
	Common earthworm
	Great crested newt
	Common frog
	Bank vole
	Common honey bee
	Common lizard
	Brown rat
	Rabbit
	Adder
	Feral pigeon
	Willow Ptarmigan

SPACE reference group	Common name
Medium ($0.5 - 10 km^2$)	American mink
	Common toad
	Water vole
	Pheasant
	White-tailed deer
	Roe deer
	Badger
Large ($>10 km^2$)	Greylag goose
	Mallard duck
	Red fox
	Moose
	Gray wolf

Figure 3-1. Spatial groupings of SPACE representative species.

To evaluate the appropriateness of using different spatial scales of assessment, a hypothetical test case was derived to allow the spatial groupings in Figure 3-1 to be evaluated alongside 'human scale' assumptions. A range of radionuclides was selected and these were categorised according to whether they were associated with high, medium or low mobility in the environment (Figure 3-2).

Environmental mobility category	Radionuclide
High	C-14
	Cl-36
	I-129
	Tc-99
Medium	Cs-137
	Np-237
	Pb-210
	Po-210
	Ra-226
	Se-79
Low	Th-230
	U-238

Figure 3-2. SPACE radionuclides and categorised environmental mobility.

A spatial model was then created in GIS with an overall assessment area of 400 km^2 and a spatial resolution of either 50 m^2 (for small and medium ranging populations) or 100 m^2 (for large ranging populations). Within the overall grid, three randomly selected release points were selected from within a 3 km radius of a disposal facility that was assumed to be located in the centre of the grid. A unit release of each radionuclide was assumed to occur at each release point with transport from these points in plumes that were set according to the mobility groups for radionuclides. Beyond 10 km from the release points, activity concentrations were assumed to be zero. Overlapping of plumes allowed for higher activity concentrations to form.

The overall spatial scale assumptions evaluated were:

- Typical human averaging assumption - 2E4 m^2;
- Minimum home range for each representative species;
- Maximum home range for each representative species; and
- SPACE reference grouping spatial scales.

For each spatial averaging approach, 1,000 randomly selected points were sampled with each point representing a sampling replicate for the population under assessment (Figure 3-3). Following this approach, activity concentrations were derived as input to the ERICA dose assessment tool for each of the spatial scale assumptions.

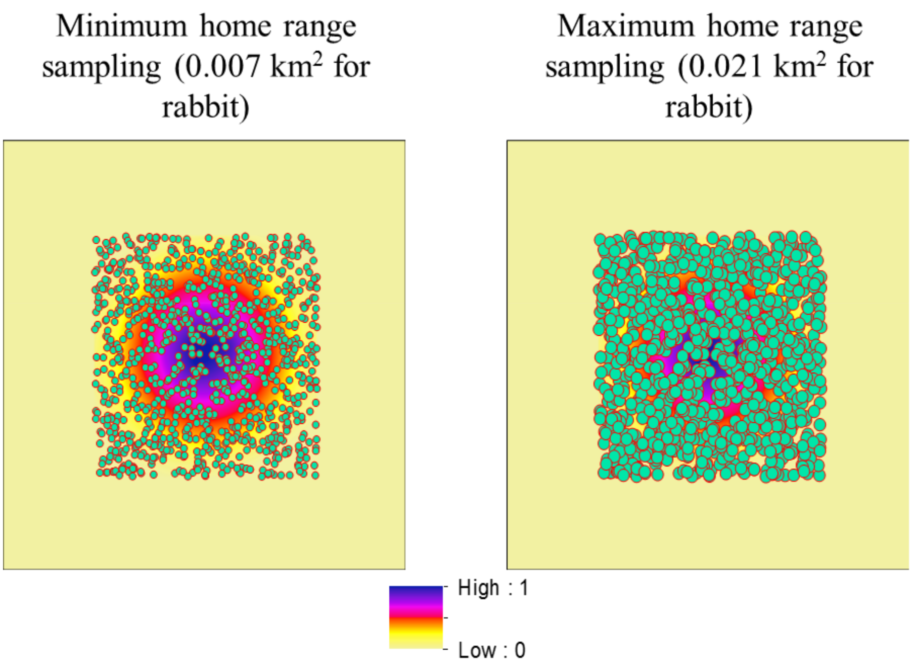


Figure 3-3. Illustration of sampling approach for a representative population using minimum and maximum home range assumptions.

For highly mobile radionuclides such as C-14 and I-129 dose rates per unit activity were broadly similar irrespective of the spatial scale assumptions although some variation was observed for the more mobile species (Figure 3-4). Where variation was observed, use of either a human averaging or a SPACE reference group assumption was conservative in most instances.

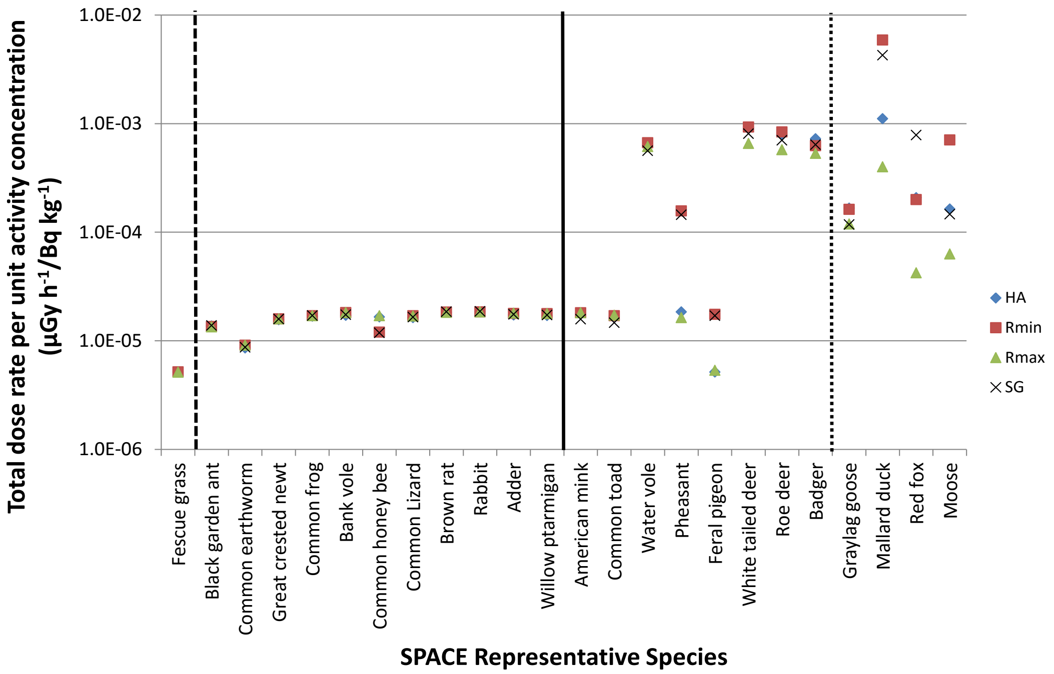


Figure 3-4. Dose rate per unit activity to representative species from I-129 for immobile (left section), low mobility (second left section), medium mobility (third left section) and highly mobile (right section) species.

For radionuclides with a medium environmental mobility, greater variation was observed in the less mobile biota species than was observed for the highly mobile radionuclides. Use of a human averaging approach was again found to be conservative. This was also found to be the case for the less mobile radionuclides.

In general, human spatial averaging assumptions were found to provide conservative or at least comparative assessments of NHB doses to populations with dose rates being within 10% of the maximum dose rate calculated across all averaging approaches. Of the 432 radionuclide-organism combinations evaluated, <15% showed a greater than 10% difference between human averaging assumptions and other spatial scales. The results of the study were however provisional since they relate to only one simulated release scenario and one assumption around human assessment scales. Furthermore, no consideration was given to habitat preferences or land use. The population scales applied for representative biota were also derived using a generic scaling value, which may not be appropriate for all populations. Nonetheless, the results lend confidence to the use of human averaging scales within assessments where the aim is to demonstrate protection of populations. It was suggested however that, in undertaking assessments, the biosphere should be considered both in terms of human use and use by non-human populations at an early stage in order to alleviate any concern from stakeholders that the environment is not being given due consideration and to ensure that model discretisation is appropriate for both humans and biota populations of interest.

Discussion

A critical review has been made of international programmes and associated literature that has allowed the rationale for addressing spatial and temporal scales within both human and non-human biota dose assessments to be evaluated. A critical aspect of the implementation of this rationale is to know what populations of non-human biota should be the object of protection for any particular assessment.

ICRP Publication 124 consolidates the suite of ICRP recommendations on environmental protection and provides further guidance on their application. It places the assessment of potential impacts on animals and plants within the existing system of radiological protection. In particular, it provides a mechanism for allowing environmental considerations to be included in the identification of the best management options, as part of the optimisation process. Noting this, and the different doses which might arise for alternative management options, further consideration could be given on how to compare the radiological significance of radiation doses to different biota (including humans) at different times and in different places.

3.3 WORKSHOP ON LONG-TERM DOSE ASSESSMENT FOR CARBON-14

Karen Smith presented.

A workshop on long-term dose assessment for C-14 was held in Aix-en-Provence, France, in April 2015, hosted by IRSN. The workshop followed a series of activities that have been organised through BIOPROTA on the subject of C-14 dose assessments. Whilst the work programme to date has helped to improve C-14 assessments, uncertainties remain and C-14 continues to be a key contributor to dose in many assessments. The workshop had the objectives to provide a forum for the presentation and discussion of new data and modelling work, since the last BIOPROTA work on C-14; to share application experience; and to consider possibilities for collective data interpretation and consideration in assessments, including developing ideas for future collaboration.

The workshop was attended by 15 participants and 14 presentations were given with time also being allocated to discussion sessions. Two broad sessions were scheduled, one to present and discuss data sets and one to present and discuss modelling approaches and uncertainties. Particular points arising in discussions were:

- Short-term processes need to be well understood to inform long-term model development and to ensure that such models are appropriately conservative. Consideration also needs to be given to the appropriate selection of values to represent processes in the long-term.
- Information is required on carbon pools, particularly in aquatic environments and wetlands / mires and whether these carbon pools are in equilibrium. In this regard, there is the potential to learn from other communities such as the climate-change community or wetland and peat scientists.

There was considerable interest among workshop participants in model-data and model-model comparison exercises with data sets being presented and discussed. Data sets included:

- IRSN monitoring data from a field site close to Cape de la Hague in France for which an inter-comparison exercise has already been undertaken by IRSN and SSM.
- Laboratory and field experiments on the soil to plant transfer of methane and carbon dioxide enriched in C-13, undertaken by University of Nottingham on behalf of RWM.

The potential for additional data sets to be sourced from Duke Swamp research programmes (potentially to allow testing of the BIOPROTA GBI methodology in addition to C-14 models) and from monitoring programmes undertaken by EdF and the Food Standards Agency was also discussed. It was also suggested that data could be researched in relation to mires to identify relevant assessment data and whether data sets could be made available to allow model testing and development for these important northern latitude ecosystems.

3.4 PRESENTATION OF THE BIOPROTA FORUM AND ASSOCIATED ACTIVITES AT INTERNATIONAL CONFERENCES

In 2014/15, two relevant international conferences were identified at which presentations of BIOPROTA and associated work programmes were made.

3.4.1 Regional Congress of the International Radiation Protection Association

Danyl Perez-Sanchez attended the IRPA Regional Congress that was held in Buenos Aires and gave a presentation on the BIOPROTA International Collaborative Forum for Improving Safety Assessment in Radioactive Waste Management.

In response to the presentation, a number of conference attendees from Brazil, Argentina and Mexico expressed an interest in BIOPROTA. Those expressing interest were involved in regulation and commissioning of nuclear energy and NORM and legacy site management. Whilst the organisations do not have HLW programmes, interest was expressed in relation to L/ILW. It was noted that there could be options to involve these organisations in BIOPROTA, for example, through the IAEA MODARIA follow-up programme.

3.4.2 International High-level Radioactive Waste Management Conference

Graham Smith attended the 2015 international conference on high level radioactive waste management that was held in South Carolina, USA, run by the American Nuclear Society. He gave a presentation on international cooperation on biosphere assessment, as illustrated by the BIOPROTA Forum. Other papers were presented on biosphere issues, including the BIOPROTA geosphere-biosphere methodology. A full set of papers from the conference is available from www.ans.org.

3.5 IUR FORUM

The IUR held a workshop in June 2014 on the harmonisation of radioecology and international networking to which a range of global, regional and topical networks and international organisations were invited to attend, including representatives of the BIOPROTA forum. The objective of the forum was to improve networking of radioecology communities in order to promote a harmonised and coordinated development process for radioecology. Presentations were given from each of the networks / organisations that were represented to provide background information and priorities in terms of research and expertise.

As a result of the workshop there was a collective decision to launch the ‘FORUM’ that would be operated by IUR. The following objectives were assigned to the FORUM:

- Global integration and construction of consensus
- Communication
- Maintenance of expertise

A working plan is to be developed and additional network partners invited to participate.

The FORUM is intended to provide a mechanism for interaction between different experts in different communities. Questions can be raised with the IUR for dissemination to relevant experts.

4. BIOPROTA ARRANGEMENTS IN 2015/16

Arrangements for the BIOPROTA forum for 2015/16, including feedback from the annual sponsoring committee meeting are presented in this section.

4.1 BIOPROTA CHAIR FOR 2015/16

Danyl Perez-Sanchez (Ciemat) offered to continue to chair the BIOPROTA forum for a second year. The efforts of Danyl in chairing the forum for the past year were gratefully acknowledged.

4.2 WORK PROGRAMME IN 2015/16

A number of suggestions have been put forward as possible projects to take forward in 2015/16. These included:

- further model testing against data sets for C-14;
- reviewing literature for data on processes relevant to radionuclide cycling in mires to allow conceptual model and model test cases to be developed;
- coherent assessment of non-radiological impacts from waste disposal alongside the radiological impacts;
- testing of the BIOPROTA GBI methodology using Duke Swamp research data; and,
- review and enhancement of the IAEA BIOMASS-6 Reference Biospheres Methodology, which could potentially be run in parallel with an IAEA MODARIA follow-up activity.

Each of these project ideas was presented and discussed in more detail in a workshop that was held in the days following the annual workshop summarised in this report. Further information is available from the report of that workshop on continuing issues in biosphere assessments for radioactive waste management.

4.3 2016 ANNUAL MEETING

The venue of the 2016 annual meeting of the BIOPROTA forum is to be confirmed. FANC has provisionally offered to host the meeting in Brussels, Belgium.

4.4 FEEDBACK FROM THE SPONSORING COMMITTEE MEETING

At the time of the workshop, BIOPROTA memberships had been confirmed with 21 of 24 organisations who were members in 2014. Additional interest had also been received from PNNL in the USA and some Latin American organisations. Contacts are to be followed up with potential new members of the forum.

Appreciation was expressed from all member organisations to organisations hosting the various project meetings and workshops.

An overall budget for the BIOPROTA activities in 2014/15 was requested to be provided by the Technical Secretariat to sponsoring organisations. This should provide a breakdown of costs and identify where support, other than financial, has been provided by member organisations.

A request was made for agendas to be made available in a timely manner to inform potential participants and assist in obtaining internal permission for travel and attendance.

APPENDIX A. LIST OF PARTICIPANTS

Participant	Affiliation
Elena Abarca	Amphos 21, Spain
Danyl Perez-Sanchez	CIEMAT, Spain
Beatriz Lourino-Cabana	EdF, France
Markus Hugi	ENSI, Switzerland
Koen Mannaerts	FANC, Belgium
Anna Filonova	FMBC, Russia
Graham Smith	GMS Abingdon Ltd (BIOPROTA Technical Secretariat), UK
Jongtae Jeong	KAERI, Korea
Mi-Seon Jeong	KORAD, Korea
David Read	Loughborough University, UK
Alessandro Proverbio	Low Level Waste Repository, UK
Andreas Poller	Nagra, Switzerland
Sanae Shibutani	NUMO, Japan
Neale Hunt	NWMO, Canada
Lauri Parviainen	Posiva, Finland
Karen Smith	RadEcol Consulting Ltd (BIOPROTA Technical Secretariat), UK
Talal Almahayni	SCK.CEN, Belgium
Ulrik Kautsky	SKB, Sweden
Anne-Maj Lahdenperä	SROY, Finland
Shulan Xu	SSM, Sweden