BIOPROTA

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

Report of Workshop

12 – 14 June 2002

Hosted by ANDRA, Chatenay-Malabry

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History

Draft report Version 0.1 prepared by Enviros QuantiSci, distributed to those organisations which provided input.

Report Version 1.0 prepared by Enviros QuantiSci in light of feedback on Version 0.1

Contents

1 INTRODUCTION, SCOPE AND OBJECTIVES

Following an initiative of Per Strand (NRPA) and discussions at the ANDRA-IUR workshop in Nancy[1], an idea was developed for a collaborative programme to address key issues in biosphere aspects of assessment of the long-term impact of radionuclide releases associated with the disposal of solid radioactive wastes. The concept is described in Appendix A.

Accordingly, a wide variety of national agencies and authorities with responsibility for management of radioactive waste or in the regulatory supervision of such management were invited to a workshop hosted by ANDRA in Chatenay-Malabry. The objectives were as follows:

- for participants to present and exchange information on the Key Issues of relevance to their organisations,
- to identify the Common Key Issues and Themes,
- to discuss collaborative ways forward to address the Common Themes,

The response of organisations to the invitation is detailed in Appendix B. A total of 20 organisations expressed interest, including 13 operator bodies, 5 regulatory authorities and two national technical support organisations, one specifically supporting the national regulatory authority. 18 of the organisations participated or contributed material to the workshop. Two others asked to be kept informed of developments.

2. PRESENTATIONS FROM PARTICIPANTS

15 organisations provided input for presentation and discussion at the workshop. Some included extensive background and technical explanation, while others were concise statements on the Key Issues and how they might best be addressed. The highlights from each are given below[2].

ANDRA

- ANDRA has interest in shallow and deep disposal facilities, and both radionuclides and toxic substances

- Priority contaminants are facility/waste dependent:
  - for Centres Manche and Aube: Ra-226, C-14, Tc-99, Ag-108m, Pu-239, Sr-90, Cl-36, Th-232 and Nb-94, and B, Pb, Cr, Cd, Ni, U, Be, CN^-
  - for Centre TFA: H-3, Cl-36, Ag-108m, C-14, and As, Hg, Pb, Cr, Ni, CN^-

[1] Mobility in Biosphere of Iodine, Technetium, Selenium and Uranium. ANDRA- International Union of Radioecology Nancy, 3 – 5 April 2002

[2] Where supplied, electronic and/or paper copies of the full presentations have been retained and can be made available on request.

  - for deep HLW disposal: I-129, Cl-36, Tc-99, Se-79, Cs-135 and Nb-94, and B, Cr, Ni, U
  - special issues with Ra containing waste, also with As, Pb, Cr, Cd, Hg, Sb, Ni, Be, B and Cr, and with graphite waste

- Priority processes and parameters are element dependent:
  - Iodine: aspersion factor and transfer to milk
  - Technetium: aspersion factor and soil K_d
  - Selenium: aspersion factor and transfer to animal products
  - Uranium: soil K_d
  - Boron: aspersion factor, soil to fruit transfer and soil K_d
  - Chromium: soil to leaf and root vegetable transfer, and soil K_d

- BIOPROTA Key Issues
  - Up-to-date database for transfer parameters, with uncertainties; need to understand the reason for the variations observed and to correlate to system conditions
  - Experimental studies for transfer to animal products (I, Se)
  - Model inter-comparison
  - Atmospheric transfer models for solid waste disposal, H-3, C-14, methylation of Se
  - Comparison/special models for C-14, Cl-36 and I-129
  - Assessing effect of environmental change: soil, fauna and flora evolution and geomorphology
  - Modelling of detailed processes in aspersion
  - Taking account of the chemical toxicity and radionuclides at the same time, including synergistic effects
  - Criteria for environmental impact assessment and effects on non-human biota
  - Use of indicators

BNFL

BNFL sees advantages in a collaborative research program to:-

- Demonstrate the continuance of best practice
- Reduce uncertainties in appropriate areas of assessments
- Share experience with other organisations
- Maximise the efficiency of resources through cost sharing

BNFL has interests in safety cases and assessments of radioactive liquid and aerial discharges, solid radioactive waste disposal, assessment of other potential waste forms and management of contaminated land. Regulations, time-frames for assessment and assessment end-points are not the same for all these situations.

Dominant exposure pathways include:

- Ingestion of contaminated foodstuffs and soils/sediments

- External irradiation
- Inhalation of radioactive aerosols and gases
- Consumption of contaminated waster

Dominant radionuclide contributions include:

- H-3, C-14: Inhalation of gaseous species
- Cl-36: Concentration in terrestrial foodstuffs
- Sr-90, Tc-99, I-129, Cs-137: Concentration in marine foodstuffs
- Pb/Po-210: Concentration in terrestrial foodstuffs
- Ra-226: Concentration in terrestrial and marine foodstuffs, and in soil/sediments
- Np-237 and U: Concentration in soil/sediments

Other issues include uncertainties arising from environmental change, such as changes in fauna and flora and flushing of land by the sea. It may be worth considering a comparison of chemo-toxicity and radio-toxicity for selected elements.

ENRESA/CIEMAT

The most recent assessment experience comes from the ENRESA 2000 performance assessment of HLW disposal. Biosphere issues arising from this exercise are as follows. From ENRESA 2000 I-129, Cs-135, Se-79, Sn-126, C-14, and Cl-36 are the most important radionuclides for the Reference Scenario.

A major issue of concern in the R&D ENRESA program is the Geosphere-Biosphere Interface and its detailed analysis is carried out because of its effect on final concentrations in the biosphere. Specific issues relate to:

- Dilution rates,
- Chemical conditions and
- Modelling approach

In the long-term biosphere modelling:

- The Reference Biosphere Methodology is applied to long-term analysis as it was developed in BIOMASS,
- Climate modelling implications for PA are investigated in BIOCLIM,
- Dose dispersion due to different environmental conditions BIOMOSA

The final objective is to understand uncertainties in biosphere assessment. Future focus should be upon limiting the uncertainties through understanding of the systems under assessment.

A difference arises between modelling exposures over the lifetime of a human and modelling a biosphere system, subject to change, over hundreds or thousands of years.

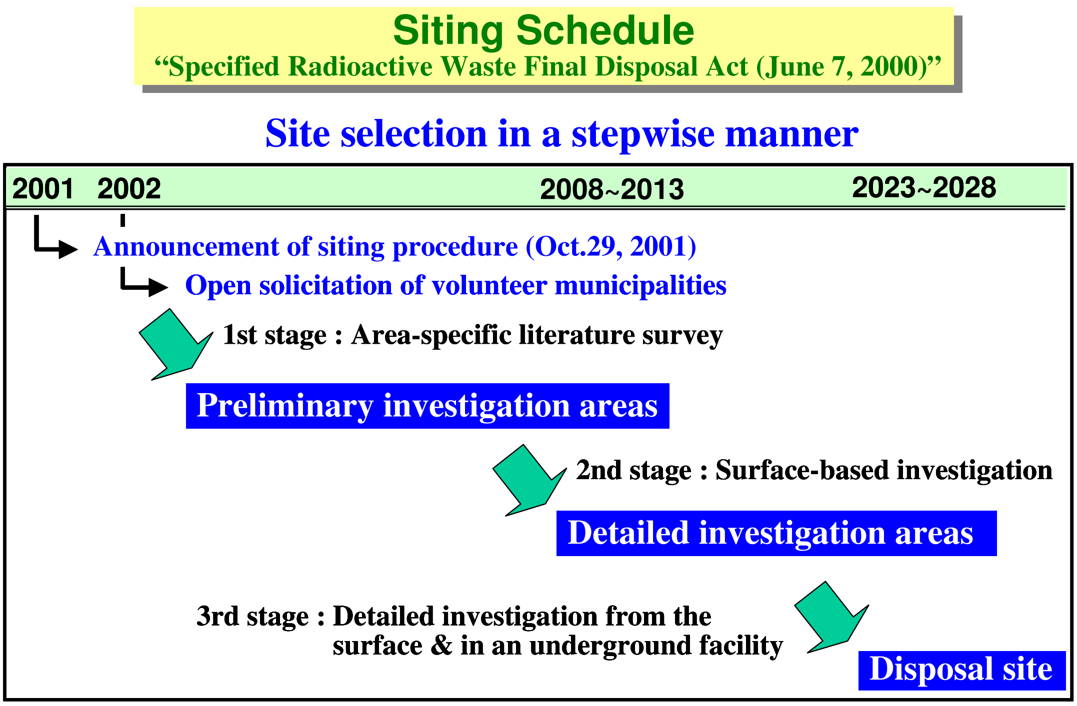
Key Technical Issues and options include:

- Developing consistent treatment of environmental change throughout the performance assessment,
- Improving assessment of doses for some key radionuclides, as presented and discussed at the IUR-ANDRA workshop,
- Lack of data for a set of important radionuclides is always a problem in the Biosphere analysis
- Assessment of long term behaviour of actinides in the biosphere, and
- Use of natural analogues to better understand the system and environmental change.

NUMO

NUMO, Nuclear Waste Management Organization, is the implementing organisation in Japan responsible for HLW disposal. The most recent performance assessment for HLW dispsoal in Japan is 'H12' which was made by JNC, Japan Nuclear Cycle Development Institute and published in 2000. The H12 assessment was site generic. The biosphere part of the H12 assessment was based on BIOMASS Theme 1 Reference Biosphere methodology, applied to the Japanese assessment context.

The NUMO siting schedule for a HLW repository was presented as follows.



To identify Key Issues for the Biosphere, the process has been for each scenario of release of radionuclides from geosphere to biosphere, to examine the biosphere model to:

- identify radionuclides and exposure pathways via environmental media which give peak doses,
- identify migration and accumulation processes resulting in contamination of those media,
- identify parameters in the model which are poorly characterised but important.

The types of data required include:

- Biosphere system description data
- Radionuclide dependent data
- Geosphere-biosphere interface zone data

The key system description data fall into categories as follows:

Water Bodies: The basic information (size, volumetric flow) about water bodies is very important, since it determines the scope for dilution of radionuclides released from the geosphere. It is sometimes not clear in the assessment framework whether any near surface aquifer should be considered as part of the biosphere or as part of the geosphere. However, it is clear that information on near surface aquifers is relevant to the overall PA, as well as details of their hydrological connection with the surface water bodies. Such near surface groundwater flow characterisation could be investigated in a similar manner to the deeper groundwater flow, but this is only practical in a site specific case.

Soils: The characterisation of the soils according to type is fundamental to being able to chose values of model parameters relevant to radionuclide behaviour for long term accumulation and uptake into the foodchain. The information suggested for soils can be linked to water body information, to develop an understanding of how radionuclides may be transported to the surface in groundwater, as in BIOMASS Theme 1, Example Reference Biosphere 2B. The scope for the interaction of radioactive gas releases from the geosphere can also be inferred from such characterisation.

Ecosystems: Ecosystem community characteristics should be investigated for any areas of natural and semi-natural land as well as land significantly affected by current human activity. Understanding of the ecosystems is important to the development of the models for assessment of doses to humans. It is additionally important to the extent that endpoints may need to be developed and assessed relevant to the protection of the environment itself. In this case, a clear understanding of the initial conditions at a site is important, so as to be able to determine whether there are any particularly sensitive or important components of ecosystems (such as an endangered species) requiring special attention. Such interest will arise with respect to impact assessments for operations as well as being of interest post-closure.

Human behaviour: The BIOMASS tables describing human behaviour help to define candidate critical groups and well as to showing how humans interact with the biosphere system, potentially affecting radionuclide migration and accumulation in the biosphere, but also affecting the release into the biosphere through the GBTZ. It may be of interest to assess the potential for human exploitation of the site environs, as alternatives to present day behaviour relevant to system change and to variant critical groups.

Key radionuclides and processes are identified as follows.

- Although detailed modelling points to quite specific exposure pathways and processes, the quality of the information for those pathways is not always very well supported. This means that a broader range of exposure pathways might be worthy of further investigation.
- Results from Example Reference Biospheres studied under BIOMASS Theme 1 do not help to determine the relative significance of the individual radionuclides. However, they do confirm, or identify additional, potentially relevant pathways for the radionuclides considered.
- For many assessments, irrespective of the engineered barrier system, ecosystem and climate state, there are relatively few radionuclides that dominate doses to humans. The key radionuclides are Th-229 ingrown from Np-237, Se-79, I-129, Cs-135, plus Cl-36, C-14, Tc-99 or Sn-126 according to the waste type.
- The key pathways are ingestion of agricultural products grown on contaminated soils (either crops or animal products or both depending on the radionuclide). Additional pathways are associated with the ingestion of wild products such as fungi, fish or shellfish, or external irradiation (Sn-126) from soils and sediments or inhalation of re-suspended dusts, again depending on the waste type and radionuclides assessed.
- The comparatively few radionuclide/pathway combinations help to identify those key processes for which resources should be expended in order to obtain reliable information and data. Key processes which dominate in many assessments include:
    - irrigation (including wet deposition and foliar interception);
    - root and foliar uptake by crops (including K_d);
    - contaminant uptake across animal tissues; and
    - concentration factors for fish and shellfish from surrounding water.
- Justified data are also required for human activities and the related exposure pathways, in particular dietary habit information, since the ingestion pathway is important for many of the key radionuclides.

An area of special interest is assessment of processes at the geosphere-biosphere interface zone, since this significantly affects radionuclide concentrations seen in biospheric media. Significant FEPs include:

- Biological activity
- Erosion, sediment movement and redistribution,

- Groundwater and pore water movement,
- Surface water bodies and flow,
- Sorption and mineral precipitation,
- Groundwater and porewater chemistry, as it affects solubility and sorption,
- Gas flow,
- Seismic and tectonic activity, and
- Igneous and metamorphic processes.

NUMO notes the following links between site investigation and biosphere aspects of performance assessment.

- Radionuclide behaviour at the site: Data on background radionuclides (both natural and artificial) including concentrations of radionuclides in groundwaters, soils, water bodies and sediments, and foodstuffs grown in or obtained from them.

- Performance confirmation experiments and measurement: These might include measurement programmes operating over a few tens of years, sufficient to test assumptions about relatively long term behaviour of radionuclides in the biosphere.

- Use of natural background data at the site: Radionuclides of interest include the natural U series decay chain radionuclides, C-14, K-40, fall-out radionuclides including Chernobyl fall-out and residual activity from atmospheric weapons testing.

- Supporting assumptions for transfer at, or through the GBIZ: Tritium measurements may provide useful information on the age and movement of near surface groundwaters. It may be practical to combine system description data with these radionuclide data to produce a basis for verifying models for transfer of repository derived radionuclides across the GBTZ and into relevant environmental media, such as foodstuffs.

All the above appear practical within the time-frame of repository development.

NAGRA

NAGRA is interested in deep disposal of HLW and L/ILW and studies of current systems and their history are relevant since the types of change in the future are likely to be the same. NAGRA has been studying river terraces as primary receptor for groundwater release of radionuclides because this gives more conservative results. However, changes in waste streams and in assessment of the effectiveness of accumulation of contaminated sediment in lakes and changes to the lake may be an interesting process to consider.

Concerning data needs, physical systems are best considered on a site specific basis, but radionuclide uptake in the foodchain is not considered to be very site specific. NAGRA is not considering chemical toxicity, but the important radionuclides include those mentioned above. However, changes in the waste source term on in assessment of the effectiveness of engineered barriers means that future assessments may have to consider potentially significant release to the biosphere of other radionuclides. Natural analogues could provide a useful basis for improving confidence in biosphere assessment assumptions.

United Kingdom Nirex Limited (NIREX)

Nirex consider the issues in terms of the radionuclide sources to the biosphere, transfers through the biosphere and exposures of man and other biota.

Sources include:

- Flow and natural discharge of contaminated groundwater;
- Abstraction of contaminated groundwater from wells;
- Flow of bulk gas contaminated with radionuclides and its discharge to soils or to the overlying atmosphere;

Exposure routes include:

- Inhalation of aerosols and radioactive gases;
- Ingestion of foodstuffs, soil and sediment, and water;
- External irradiation from soils, sediments, water bodies and contaminated artefacts;
- Uptake through the intact skin and from wounds.

Nirex have identified primary, secondary and minor exposure pathways. Minor pathways were not discussed further. Primary pathways and related issues include:

- Ingestion of contaminated drinking water obtained either from surface water bodies or from wells
    - Flux of contaminated groundwater;
    - Spatial variability of the distribution of contamination with depth;
    - Degree of dilution of the contaminated groundwater with uncontaminated water;
    - Rate of ingestion of drinking water;
    - Dose-per-unit-intake factors.
- Ingestion of terrestrial plant and animal products contaminated as a result of groundwater discharge or by use of water from wells;
    - Factors affecting plume location and dilution
    - Surface and subsurface hydrology of specific catchments at the present day and of controls on those hydrological characteristics;
    - How climate, landform and, hence, hydrology will evolve in the long term;
    - How soil and vegetational properties will change on shorter timescales;
    - The effects of human activities, notably in respect of water management;
    - Stable element concentrations in the soil;

  - Radionuclide concentration in the soil and the nature of the migration and retention of these radionuclides;
  - Radionuclide uptake by plants from soil or from irrigation;
  - Translocation factors within plants;
  - Foodstuff and water intake rates by animals;
  - Bioaccumulation and distribution factors in animals;
  - Intake rates of contaminated plant and animal products by man;
  - Intake-to-dose factors by ingestion.
- Inhalation of radioactive gases released from soils, sediments and biota; and Ingestion of terrestrial plant and animal products contaminated as a result of the discharge of radioactive gases.;
  - Metabolism of the gases in the soil zone;
  - Atmospheric dispersion;
  - Exposure of individuals to contaminated air;
  - Relationship between exposure and effective dose;

The relationship between release, exposure mode, pathway and uncertainties, is illustrated in some detail in the following Table, for Secondary Pathways. Further information is available in a draft Nirex Technical note discussed at the BIOPROTA meeting, however, the information here should not be cited without further reference to NIREX.

Route of Release	Mode of Exposure	Pathway	Significant Uncertainties
Groundwater discharge	Inhalation	Solid radioactive aerosols resuspended from soils and sediments.	The degree of sorption to soils and sediments has to be characterised for the pathways of primary importance. However, some distinctions may arise in the degree of sorption to the resuspendable surface layer compared with lower soil layers. Also, consideration has to be given to the nature of the radionuclide concentration profile in the soil, as this also determines the concentration in the resuspendable layer. Overall, the most important uncertainty is likely to be the magnitude of the resuspension factor that relates radionuclide concentrations in air to those in the soil.
		Radioactive gases produced from soils, sediments and biota contaminated with radionuclides.	The degree of volatilisation of radionuclides from contaminated soils is considered to be highly uncertain. This applies particularly to ^{36}Cl, ^{79}Se, ^{99}Tc, ^{126}Sn and ^{129}I.
	Ingestion	Contaminated aquatic animal products.	Concentrations of radionuclides in surface waters are of relevance in the context of pathways of primary importance. Therefore, the main uncertainty is in concentration ratios for the edible parts of fish relative to fresh waters. However, in practice, because of the relative rates of consumption of drinking water and fish, this uncertainty is only of importance for radionuclides with concentration ratios of greater than 0.025 $m^3\,kg^{-1}$ on a fresh weight basis.

Route of Release	Mode of Exposure	Pathway	Significant Uncertainties
		Contaminated soils and sediments.	The degree of sorption to soils and sediments has to be characterised for the pathways of primary importance. Also, consideration has to be given to the nature of the radionuclide concentration profile in the soil, as this also determines the concentration in the superficial layer that may be ingested. The main additional uncertainty is on the rates of soil and sediment consumption that should be assumed.
	External	External irradiation from soils and sediments.	The degree of sorption to soils and sediments has to be characterised for the pathways of primary importance. Also, consideration has to be given to the nature of the radionuclide concentration profile in the soil, as this determines the relationship between soil concentration and dose rate.
Well abstraction	Inhalation	Solid radioactive aerosols resuspended from soils and sediments.	The degree of sorption to soils and sediments has to be characterised for the pathways of primary importance. However, some distinctions may arise in the degree of sorption to the resuspendable surface layer compared with lower soil layers. Also, consideration has to be given to the nature of the radionuclide concentration profile in the soil, as this also determines the concentration in the resuspendable layer. Overall, the most important uncertainty is likely to be the magnitude of the resuspension factor that relates radionuclide concentrations in air to those in the soil.
		Radioactive gases produced from soils, sediments and biota contaminated with radionuclides.	The degree of volatilisation of radionuclides from contaminated soils is considered to be highly uncertain. This applies particularly to ^{36}Cl, ^{79}Se, ^{99}Tc, ^{126}Sn and ^{129}I.
	Ingestion	Contaminated soils and sediments.	The degree of sorption to soils and sediments has to be characterised for the pathways of primary importance. Also, consideration has to be given to the nature of the radionuclide concentration profile in the soil, as this also determines the concentration in the superficial layer that may be ingested. The main additional uncertainty is on the rates of soil and sediment consumption that should be assumed.
	External	External irradiation from soils and sediments.	The degree of sorption to soils and sediments has to be characterised for the pathways of primary importance. Also, consideration has to be given to the nature of the radionuclide concentration profile in the soil, as this determines the relationship between soil concentration and dose rate.

Overall, the main sources of uncertainty include:

- Appropriate generic descriptions of surface and near-surface hydrogeological and hydrological conditions for use with reference biospheres in a specified assessment context;
- The biogeochemistry of some key radionuclides in soils and their uptake by plants;
- Aspersion irrigation and radionuclide translocation to the edible parts of plants;
- Some specific aspects of radionuclide transfers to animals;
- Uptake of ^{14}C by plants following releases of $^{14}CH_4$ and $^{14}CO_2$ to the soil zone;
- The definition of appropriate potentially exposed groups;
- The incorporation of long-term climatic and environmental change into assessment studies.

ANPA

ANPA interests in solid radioactive waste management arise from the on-going implementation of decommissioning activities. Of special interest is the need for a disposal facility for LLW. The envisaged date for an available repository is 2010.

ANPA recently set up a biosphere research program (BRP). The BRP objective is to perform investigations about the necessary instruments for the evaluation of the repository's PA, with renewed attention to accidents and unplanned events. This is not only a conceptual choice, but deals directly with the role of the Agency that is called upon to licence both construction and operation of the facility.

The activities involved are necessarily multidisciplinary and require the competence of different experts in environmental and climatic science, radioprotection, waste management, civil and mechanical engineering, hydrology, hydraulics, geology, chemistry, thermodynamics and geochemistry, etc.

The first step of the program is the exact definition of the targets and the justification for each of the investigated scenario, with attention to:

- safety requirements and
- risks and risk perception.

The second step is the definition of the conceptual model and the most complete characterisation of the repository systems and the site. At this point is necessary to focus on:

- site characterisation;
- waste characterisation;
- evolution of site conditions;
- performance of engineered barriers in relation to both natural and human processes and events.

When the two steps have been completely defined and all data made available, it will be possible start the translation of the conceptual model into the mathematical model, taking care to provide facilities to address the treatment of sensitivity and uncertainty that will characterise the performance assessment. At this point, it is necessary to establish the role of PA during the operational life of the facility and in post-closure periods, and particularly to develop:

- a model of the structure (source term, specific site);
- a model of transport (air, soil, superficial water, groundwater);
- a model of exposure (inhalation, ingestion, direct irradiation);
- a demographic model (for assessing effects on humans).

Sensitivity analysis and uncertainty analysis are essential in performance assessment in order to evaluate and optimise the design of the repository facility. They are also very important in justifying preliminary assumptions and finally can be used in comparisons between models of different complexity.

The recent commencement of the BRP made it impossible to write a specific contribution to the work, but ANPA has serious interest in the topic and is pleased to participate in the ensuing program.

POSIVA

It was highlighted that Finnish solid waste disposal criteria include dose constraints for several thousand years and constraints on release rate to the biosphere after several thousand years[3]. Changes in the environment which have to be considered include at least those arising from land uplift.

The **constraint for the most exposed individuals**, effective dose of 0.1 mSv per year, applies to a self-sustaining family or small village community living in the vicinity of the disposal site, where the highest radiation exposure arises through a range of pathways. In the environs of the community, a small lake and a shallow water well is assumed to exist.

In addition, **assessment of safety shall address the average effective annual doses to larger groups** of people, who are living at a regional lake or at a coastal site and are exposed to the radioactive substances transported into these watercourses. The acceptability of these doses depend on the number of exposed people, but the doses shall not be more than one hundredth – one tenth of the constraint for the most exposed individual.

Guide YVL 8.4 specifies nuclide specific constraints for the activity releases to the environment are as follows:

- 0.03 GBq/a for the long-lived, alpha emitting radium, thorium, protactinium, plutonium, americium and curium isotopes
- 0.1 GBq/a for the nuclides Se-79, I-129 and Np-237
- 0.3 GBq/a for the nuclides C-14, Cl-36 and Cs-135 and for the long-lived uranium isotopes

[3] STUK 2001. Long-term Safety of Disposal of Spent Nuclear Fuel. Radiation and Nuclear Safety Authority (STUK), Regulatory guide YVL 8.4 (http://www.stuk.fi/saannosto/YVL8-4e.html)

- 1 GBq/a for Nb-94 and Sn-126
- 3 GBq/a for the nuclide Tc-99
- 10 GBq/a for the nuclide Zr-93
- 30 GBq/a for the nuclide Ni-59
- 100 GBq/a for the nuclides Pd-107 and Sm-151.

These constraints are based partially on biosphere analyses, e.g. SR 97's biosphere models have been applied to Olkiluoto, and partially on comparisons with natural fluxes of long-lived radionuclides.

The importance to long-term safety of **unlikely disruptive events** impairing long-term safety shall be assessed and, whenever practicable, the acceptability of the consequences and expectancies of radiation impacts caused by such events shall be evaluated in relation to the dose and release rate constraints specified above.

The considered unlikely disruptive events shall include at least:

- boring a deep water well at the disposal site
- core-drilling hitting a waste canister
- a substantial rock movement occurring in the environs of the repository.

The importance to safety of any such event shall be assessed and whenever practicable, the resulting annual radiation dose or activity release shall be calculated and multiplied by the estimated probability of its occurrence. The expectation value shall be below the radiation dose or activity release constraints. If, however, the resulting individual dose might imply deterministic radiation impacts (dose above 0.5 Sv), the order of magnitude estimate for its annual probability of occurrence shall be 10^{-6} at the most.

Disposal of spent fuel **shall not affect detrimentally species of fauna and flora**. This shall be demonstrated by assessing the typical radiation exposures of land and aquatic populations in the disposal site environment, assuming the present kind of living populations. These exposures shall remain clearly below the levels that, on the basis of the best available scientific knowledge, would cause decline in biodiversity or other significant detriment to any living population. Moreover, rare animals and plants as well as domestic animals shall not be exposed detrimentally as individuals.

Posiva's strategy for biosphere analysis welcomes clear and transparent requirements and guidance in the field of biosphere analyses from the regulator. To fulfil the requirements Posiva will:

- evaluate the evolution at the potential discharge areas at Olkiluoto for the next several thousands of years. Groundwater flow modelling will be used to identify the potential discharge areas. Sea bottom topography and sediments will be investigated to take into account the effects of land uplift (presently approximately 6 mm/a at Olkiluoto).

- study circulation and mass transfer processes (physical, chemical, micro-biological) of elements.

- carry out biosphere modelling for potential recipients at Olkiluoto (well, lake, sea, sediment that later will be exposed due to land uplift, forest, peat bog). Development of models is planned to be carried out in cooperation with SKB.

As concerns effects of human actions and consideration of other living nature, Posiva is actively seeking for international cooperation in these new research fields. For example, the progress of the FASSET project is followed.

Due to the regulatory concept, there are few potentially problematic nuclides in the Finnish biosphere assessments. However, there are some specific concerns related to C-14 and the short-lived daughters of Ra-226, especially Rn-222. The release rate constraint on C-14 is rather low and is based on the assumed enrichment of inorganic C-14 in the biosphere, . However, corrosion of metals in anaerobic conditions may produce methane and other organic compounds containing C-14, which are not retarded in the repository materials or geosphere. If C-14 is released into the biosphere as methane gas, it will not cause any significant doses. However, the situation may be different, if organic compounds containing C-14 are transformed inorganic at the geosphere-biosphere interface, e.g. due to oxidation by microbes. In any case, the release rate of C-14 from the metal parts is governed by the corrosion rate of the metals.

Release rates of Rn-222 and other short-lived nuclides may be significantly higher than that of the long-lived parent and depend crucially on conditions close to the geosphere-biosphere interface. Fortunately, there is only a small amount of Ra-226 in the spent fuel initially and for several thousands of years. Thus radon is not an essential issue in the dose calculations to be performed in the Finnish case.

In general, the actual time span of biosphere modelling in the Finnish case extends to several thousands years in the future. For periods after that, the regulator takes the main responsibility for determining the release rate constrains (which are partially based on consideration of reference biospheres) so that dose calculations are not needed. However, it is important also to Posiva to follow the development of really long-term biosphere assessments.

Posiva agrees with SKB on interests in data requirements. A particular problem of biosphere calculations in safety assessments is the large number of data values (e.g., Kd's, uptake factors in the different environments) needed and the scarcity of observations in relevant conditions. High-quality compilation, review and quality check of data needed in radiological assessments of radioactive waste is a basis for further studies and should have the priority in co-operative efforts due to its generic nature. An electronic database easy to use and access should be developed.

Any possible further experimental studies should be planned only on the basis of scientific evaluation of existing data.

The focus should be on work of experts for practicable results which can be applied in relevant circumstances, not on seeking consensus on generic issues.

SKB

SKB has a general interest in compiling, reviewing and quality checking data. Notable key data are Kd's and uptake factors. These are similar to those identified as priorities in the reviews presented at the IUR/ANDRA workshop in Nancy. See also SKB report, R-02-28, 'Element Specific Parameter Values Used in the Biospheric Models of the safety assessments SR97 and SAFE' S Karlsson and U Bergstrom, Studsvik Eco and Safety AB.

BIOPROTA's focus should be on understanding the reasons for variations in parameter values and to identify correlations to biosphere description, e.g. pH, organic content of soils. A simplistic generic compilation of best estimates or recommended values, would not be helpful unless it is supported by this type of understanding.

New laboratory work or experiments should probably be deferred until the critical review is completed. It is likely that such new work should best be carried out on a site specific basis. Nevertheless generic consideration of choice of parameters still has the potential to identify examples of unnecessary pessimism, where the current choice is physically unreasonable within the constraints of the biosphere system as currently defined.

ONDRAF/NIRAS

Within the Belgian programme, during the last 25 years, considerable experience has been gained in both the modelling and obtaining relevant parameters for the biosphere within safety evaluations of both surface disposal and deep disposal installations in the Mol-Dessel region. In the last ten years, more emphasis has been put on field research to be taken into account in evaluations of local biosphere conditions. The values for the different parameters were compared and validated with the results of the BIOMOVS program.

A biosphere model has been developed for the normal evolution scenario in which the present biosphere is assumed to be unchanged with time. This biosphere model is used in safety assessments to evaluate doses to an individual in the reference group starting from radionuclide fluxes and concentrations in the aquifers. Because of the long periods of time over which radionuclides are released, it is assumed that the levels of concentration in the various biosphere compartments remain constant or can be interpreted as time averages. Both deterministic and stochastic calculations are carried out.

Issues for further research include:

- Normal evolution scenarios with changes in the biosphere have not been considered so far because of the major uncertainties surrounding the changes in important parameter values caused by the evolution of the climate. Further studies of climate changes are needed to be able to develop a model with expected changes in the biosphere for the normal evolution scenario.

- The reference biosphere methodology that is the result of the BIOMASS program will be used to develop a new biosphere model or to extend and optimise the existing model; this is foreseen in the next two years. Ways will also be explored of comparing the results of this internationally (developments of generic biosphere models) within the EC's BIOMOSA project.

- The models developed for fruit within the BIOMASS programme will be included in future modelling of the biosphere.

- An inherent and irreducible uncertainty is the evolution of human behaviour over long periods of time. This needs to be clearly addressed in future biosphere modelling.

- The biosphere models may have to be adjusted depending on the development of complementary safety and performance indicators (which are less anthropocentric).

- Main uncertainties regarding the biosphere model input are experimental data for:
    - distribution coefficients in the root zone (Ca, Cm, Pa, Rb, Sm, Sn),
    - the concentration factor for freshwater fish (C, Ca, Cl, Ni, Np, Pa, Pd, Se, Sm, Tc, Am, Cm, Rb, Th, Zr, Nb),
    - the distribution coefficient for freshwater organisms (C, Ni, Pa, Pd, Rb, Se, Sm, Sn),
    - the mass interception factor for the different radionuclides for crop types other than grass,
    - the weathering decay constant for crop types other than grass and for element types other than iodine,
    - translocation factor between surface part and root part for root crops,
    - the soil-to-plant concentration factor (Nb, Ni, Ca, Cm, Pa, Pd, Sm, Sn, Se, Zr).

Ontario Power Generation

OPG offers the following more general observations based on previous (HLW) safety assessments (circa 1994 and 1996) that indicate specific areas where data review or updating would be useful:

- The dose is dominated by I-129, and by the soil-plant-man dose pathway. Any improvements in the data, or substantive reviews of data for I-129 in general, and this pathway in particular, would be good.

- The biosphere parameters whose uncertainty had the largest impact on total dose in these Canadian safety assessments were:

    - iodine aquatic mass-loading coefficient
    - plant/soil concentration factor for iodine
    - plant/soil concentration factor for chlorine.

- The mass-loading coefficient is the amount of iodine volatilised from surface water bodies. The values that have been used have been derived from measurements on aerosol formation over oceans, however, this is likely to overestimate what would happen over lakes. The other two parameters are the usual transfer factors.

OPG are considering working towards a biosphere model that reflected a more realistic surface layout, so it could be better coupled to pre-closure assessments, to geosphere transport models, and to biosphere evolution modelling. It could be interesting to explore whether there is international interest to form a common effort to develop such a model.

Finally, the recent NEA IGSC[4] discussions have identified the following set of discussion points regarding biosphere modelling:

- The Topical Session on the Role of the Biosphere in a Safety Case brought together a number of important issues from the perspective of radioactive waste management implementers, regulators and other stakeholders. The biosphere is important in a safety assessment since it is the place where humans and most organisms live and where regulations are made. The biosphere is more dynamic and changing than other components of the disposal system, such as the geosphere, and the evolution of the biosphere with time can significantly affect dose predictions to humans and the natural environment, and can potential affect a repository for radioactive waste. The general conclusions from the Topical Session were:

- The principal uncertainty in the biosphere is driven by climate change and the difficulty in predicting future events with confidence over long periods of time (hundreds of thousands to millions of years for post-closure safety assessments).

- Biosphere uncertainty can be addressed by using reference or example biospheres, or by using alternative safety indicators such as radionuclide concentration or radionuclide flux to the biosphere (as indicated by the recent regulatory guidance in Finland) and comparing these values with background levels in the environment near the repository.

- Most safety assessments have been conducted within the context of a reference, time-invariant biosphere in order to provide an indication of safety rather than an attempt to predict actual doses in the future.

- There is a movement in some waste management organisations towards incorporating time-evolving biospheres to complement the dose predictions from safety assessments that use static biospheres such as the well scenario or the agricultural scenario found in BIOMASS. One example of work on evolving biospheres can be found in the BIOCLIM Project funded by the European Commission, which will address the issue of glaciation, and other climate change issues.

- It is apparent that the radioactive waste management community needs to seek broader input from the long-term climate evolution community in order to improve its credibility among experts in this field. The BIOCLIM project, and other waste management initiatives in climate change will address this need and

[4] The Role of the Biosphere in a Safety Case. Integration Group for the Safety Case Topical Session. Nuclear Energy Agency, NEA/RWM/IGSC(2002)2, Organisation for economic Cooperation and Development, Paris.

will most likely result in a better understanding of biosphere evolution and how to incorporate it into the safety case.

- Some regulators feel that they are under pressure to make detailed decisions on geologic repository compliance far into the future and some stakeholders are expecting waste management organisations to make real predictions of the future evolution of the biosphere and impacts from a repository on humans and the natural environment. In this respect the NEA "safety case approach", which uses a collection of arguments in support of long-term safety of a repository, should be considered as the basis for decision making in this regard.

- The connections between regulatory guidance, waste management organisation strategies and scientific studies on the biosphere are not always clear. There are differences in regulatory guidance and regulatory requirements among the countries practising waste management which need to be resolved in order to avoid confusion amongst stakeholders. Nevertheless, progress is being made in this area through international meetings and workshop initiatives.

- International guidance from the ICRP is evolving on topics such as environmental protection, human intrusion, collective dose, optimisation and ALARA. Clarity on these issues will be very useful to regulators and implementers.

USDOE, Yucca Mountain Project

The Biosphere Group within the USDOE's Yucca Mountain Project has identified areas where additional information could enhance the biosphere model. Below is the list of these areas, although not necessarily in the order of importance.

One challenge regarding the data requirements that have been faced numerous times is related to the extrapolation of the available information to the conditions outside those for which the experimental results were obtained. For example, the majority of measurements of the soil-to-plant transfer factors were obtained for typical agricultural areas in temperate climates where soils have characteristics that are different from the soils in the Yucca Mountain region. The Yucca Mountain region is characterized by mineral soils with high pH values, extremely low organic matter, and unbalanced soil texture. The Biosphere Group believe that it would be beneficial to develop guidelines or recommendations, based on systematic analysis of available information, for application of data, such as the transfer factors or partition coefficients (K_d), to the conditions other than those for which they were collected, together with the information on the sources of variations and uncertainty.

An interesting modeling requirement implied by the US regulations (10 CFR 63) is consideration of the unlikely event of a volcanic eruption encroaching into the repository. In this scenario, the activity deposition onto plant surfaces via resuspension of contaminated soil/ash is an important process. The problem is exacerbated by the limited precipitation in Southern Nevada, which minimizes water-related removal pathways, especially for the radionuclides that are strongly sorbed onto soils. Experience indicates that, for the volcanic release scenario, deposition of activity on plant surfaces is a far more important environmental transport pathway than root uptake. Consequently, we would like to enhance the modeling to more accurately represent the conceptual models of contaminant deposition on plant surfaces and the related parameters.

The importance of foliar deposition processes reaches beyond the volcanic release scenario. Characteristic of the hot and dry climate of Southern Nevada (summer max temperature exceeding 35^{o}C and annual precipitation around 10 cm) is the need for intense crop irrigation. The irrigation is generally provided by over-head sprinkler system. For most radionuclides, activity deposition on plant surfaces from irrigation with contaminated water dominates over the activity uptake through the plant roots.

Considering the importance of foliar deposition processes in both groundwater and volcanic release scenarios, the Biosphere Group turned its attention to the associated parameters and found that, in many instances, improvement could be made regarding the data. For example, confusing and sometimes contradictory information was encountered about the parameters used to quantify the translocation process. It was not always clear, when the published experimental data and documentation were examined, what exactly had been measured in the experiment and under what conditions. For example, whether the contamination translocated from the source of contamination to other (edible) parts of the plant was through external processes, and as such could be subject to weathering, or whether it was absorbed by and translocated within the plant. How was the translocation parameter dependent on the mechanism of initial deposition, e.g., the root uptake from irrigation with contaminated water or the resuspension of contaminated soil and subsequent deposition on leaves?

The concentration ratios for the media involved in the process of resuspension of particulate matter are also of interest for biosphere modeling. These parameters include the consideration of activity concentration in the layer of soil available for resuspension, as opposed to the bulk activity concentration in the upper (15-20 cm) layer of soil; the actual activity concentration in the resuspended soil, as opposed to available activity concentration in resuspendable layer of soil; and dosimetric aspects of inhalation of resuspended soil. Knowledge of these factors could prove beneficial for enhancing the assessment of inhalation dose, especially for receptors involved in activities causing topsoil disturbance. Our calculations indicate that the inhalation dose is dominated by limited time exposures that occur in dusty environments, caused by activities that disturbed soil conditions. When the topsoil is disturbed, the transient but localized particle size distribution of suspended soil particles is quite different from that arising under static equilibrium conditions. The size distribution can have significant dosimetric implications. It would be of mutual benefit to investigate this issue and provide recommendations.

There are also some questions related to radon (Rn-222) exhalation from soils. One such question is: what are the dosimetric implications of radon decay products plate-out onto leaf surfaces? Crops can often provide large surface areas on which radon decay products can plate-out. As the result, the activity concentration of ^{210}Po in crops, especially in leafy vegetables and forage plants, resulting from the deposition of radon decay products may far exceed the activity taken up through the root system. Another radon-related area of concern involves the model of atmospheric dispersion of radon exhaled from soil, for the calculation of the inhalation dose. We have found some difficulties with both the model and the supporting data for C-14 uptake by plants. The experimental data are very scarce, especially regarding the predictions of carbon fluxes from the soil to the air and the subsequent concentrations of CO_2 in the air.

Another unique problem we have encountered and are addressing concerns aquatic pathways. The data on bioaccumulation factors for aquatic organisms are based on measurements conducted in contaminated natural systems, such as lakes, rivers, or oceans where biota are living in a quasi-static equilibrium. We were unable to find any information on the level of bioaccumulation in fish farmed in ponds filled with contaminated water but fed commercial uncontaminated food.

Also, unique to hot and dry climate, typical of many regions in the Southwestern United States, is the usage of evaporative coolers (i.e., evaporative air conditioners), which provide the means of effective and economical cooling for buildings by forced water evaporation within an air-moving system. We have been unable to find any information on radionuclide transport from the water to the air-stream in an evaporative cooling unit.

We have also identified other issues related to the long-term, sustained use of groundwater irrigation accompanied by continuous radionuclide recycling to ground water. This is more an issue of a scenario development than the data treatment, but there is a possibility that experimental evidence may be helpful in constructing a conceptual approach to this problem.

US NRC

The advantages in the BIOPROTA programme as US NRC see it, are that efforts may not only help assessments for geologic repositories but also shallow land burial and environmental assessments of residual radioactivity in the biosphere.

The programme will hopefully be able to address the uncertainties, especially those that exist, not because of natural variability, but because of the inability to "forecast" the future, which is especially crucial to any long-term performance assessment.

One of the key technical issues for the biosphere, is the need for justification by US DOE of the features, events, and processes (FEPs) included (and excluded) from the biosphere model. Representation of the FEPs can become speculative, especially in non-base case scenarios that drastically change the basic biosphere (e.g., a volcanic release for Yucca Mountain).

Guidance or insight on avoiding unnecessary caution or pessimism in making assumptions or selecting appropriate parameter sets should be a primary goal of any information provided by this project. In the past, individual FEPs or parameters have been chosen conservatively in isolation, which can result in an overall analysis, which is extremely conservative and/or useless to providing insight into risk significance.

UKAEA

UKAEA Dounreay is mainly interested in future shallow burial of LLW and existing ground contamination, as well as existing LLW disposal facilities. Account has to be taken of environmental change, and it is necessary to consider terrestrial and marine environments.

Main areas of interest include:

- the range of future climate change and environmental evolution that should be considered.
- the range of Potential Exposure Group (PEG) habits that should be considere;. Should there be standard "normal behaviour" and "conservative" PEGs used to calculate doses? If so how could this information be meaningfully presented?
- how much credit can be taken for institutional controls and for how long in controlling exposure in the biosphere in the region of interest;
- long-lived radionuclides (e.g. > 31 y half-life).

The key radionuclides in UKAEA assessments include:

- Tc-99,
- Ra-226 and daughters,
- Nb-94,
- U-234,
- Mo-93,
- C-14 and
- I-129.

The key pathways include:

- ingestion of animal products, and
- external irradiation for Ra-226 and Nb-94.

3. IDENTIFICATION OF COMMON ISSUES AND THEMES

Among the many issues raised in the presentations, some were of relatively limited interest to just a few organisations, whereas others were mentioned many times.

There was a lot of interest in improving element-dependent data relevant to calculation of doses via the foodchain, as well as other exposure pathways. However, there was also concern that the way forward should be to better understand the processes that lead variations in literature reported parameter values, rather than to develop a simplistic compilation of data. By understanding better the causes of the variations, we should have a better chance to justify selection of particular parameter values for particular biosphere systems. Apart from improving confidence in the assessment assumptions, such effort should also help to avoid unnecessary pessimism in the selection of parameter values. Therefore interest focussed on development of a **specialised database** addressing the particular issues of concern with respect to a few key radionuclides **such as Cl-36, Se-79 and I-129**. It is noted that in many cases it is possible that the data of interest exist, but they have not necessarily been accessed or made available or interpreted appropriately within the groups carrying out the long term assessments. Nirex is currently developing a biosphere database for use in assessments

For some migration and exposure pathways, there was common concern about the models used, i.e. the concerns go beyond the identification of appropriate parameter values. Further attention could be applied to the structure of the models. Particular examples concern contaminant transfer to foodstuffs following aspersion irrigation, and the distribution of actinides among soil or sediment particles. Modelling of releases of C-14 in carbon dioxide and methane also come into this category

Concerning **aspersion modelling**, there was significant interest in developing a clearer explanation and representation including:

- interception by crops at different stages of growth,
- retention and weathering of the intercepted radionuclides, and
- transfer of contaminants from external surfaces to edible parts of the internal crop.

Concerning **modelling actinides in soils and sediments**, there was significant interest in developing a clearer explanation and representation including:

- the spatial distribution in surface soils according to how contaminants arrived to the surface soil, e.g. following irrigation or as a result of upward migration from below,
- the distribution of contaminants among particles of different sizes and the implications for suspension of activity to the breathable atmosphere, and
- the effects of chemical form and particle association on appropriate choice of dose coefficient for inhaled contaminants.

In some cases, the largest assessed doses arise only after an assumed significant period of accumulation in biospheric media associated with continuous release from the geosphere over an extended period of hundreds of years or more. It is difficult to assess this long-term accumulation, based on data from relatively short monitoring or experimentation programs. In addition, the biosphere will be subject to change over the period of release. Such change may reduce the scope for continuous accumulation of contamination, but it also gives rise to possibilities for disturbance of contaminants in the surface environment, giving rise to higher or different types of exposures. Information about climate-induced changes should come from the EC BIOCLIM project. There was interest in exchanging and extending experience with **accounting for environmental change in the radionuclide migration and dose assessment models.**

Natural and man-made or man-influenced analogues were seen as one possibility for testing the adequacy of model assumptions, both in terms of identification of processes and in providing data for models or for model testing. There was particular interest in identifying analogues for transfer of contaminants from the subsurface, through soils and into fauna and flora, i.e. across the **geosphere-biosphere interface zone**. This type of data may provide information about the quasi-equilibrium concentrations arising from variations in biosphere system changes within decadal or even longer timeframes. Many biosphere assessment models are so strongly calibrated on empirical observations that the concept of validation may be meaningless. This is not the case with underlying research models , as illustrated by Nirex SHETRAN.

There was a common interest in addressing non-radioactive contaminants within radioactive waste. **Pb and B** were identified as suitable for consideration for this relatively unstudied topic. However, it was not thought practical at this stage to consider the synergistic effects of multiple contaminants, a topic where scientific understanding of the issue is generally lacking.

Another issue of common interest was the assessment of impacts on non-human biota. This issue is being explored explicitly within the EC projects FASSET and EPIC. While impacts on non-human biota were certainly of interest to participants, it was felt appropriate to monitor the output from those projects and then determine whether anything additional may need to be considered in relation to assessment of long term impacts associated with radioactive waste disposal.

There was interest in human intrusion and the assessment of the corresponding biosphere pathways. However, little detail was explored at the workshop and it was considered better to leave this issue for later consideration.

A review of the C-14 model, and in particular, behaviour within the soil, uptake in plants or conversion to carbon dioxide for potential exposure via inhalation will be considered early in the programme. Initial focus will be on C-14 more than the actinides because so many organisations note it as a key issue.

Bearing in mind the above, the details in the following Table were developed as of key interest. As such issues are investigated, the value of new **experiments and measurement programmes** may be identified. An important aspect is the provision of suitable protocols for such work[5]. Such protocols and guidance could in any event be of great value in supporting the **design of biosphere aspects of site investigation programs**.

[5] Sometimes the research used in previous assessments was carried out for other purposes. The output therefore omits details which, if they had been included, would have greatly added to the application of the results.

Key Radionuclides and Processes

Radionuclide	Facility Interest		Technical Issues
	Deep	Shallow	
H-3	N	Y	Extreme mobility – specific problem of source Organically bound forms affecting accumulation and dosimetry Gaseous/ liquid exchanges
C-14	Y	Y	CO_2 to bicarbonate system in soil CH_4 (microbial metabolism in soil zone) Exchange in canopy (photosynthesis v respiration; growth; C_3/ C_4 plants) Root uptake and recycling Use of so-called specific activity models, temporal and spatial averaging (Compare with S.A approach; need for evaluation of processes) Aspersion model parameters Uptake to freshwater fish
Cl-36	Y	Y	Soil: Plant – Why do plants accumulate physically useless chlorine. Animal products (physical understanding) Aspersion model parameters Halophytes and technical crops; organic interactions (need to consider stable chlorine levels) Distinctions in spatial distribution of Cl-36 and stable chlorine (sea salt effect) Previous modelling of Cl as Br as if conservative; Cl-36 demonstrated non-conservative
Se-79	Y	N	Soil- Plant }Stable element literature Soil- Plant – Animal } Aspersion model parameters [Methylation and volatilisation] Speciation issues: selenite – selonate – elemental selinium - organics
Tc-99	Y	Y	Soil- plant, Long-term accumulations linked to bio-availability; Aspersion model parameters Micro-anoxic regions }redox sensitive over water table and capillary fringe Kinetics of reactions }O supply and water Root pathways Fe, SO_4^-, NO_3^-
Nb-94	Y	Y	External exposure; long-term accumulation in soil and sediment; environmental change (centuries to millennia) [These timescales were estimates of characteristic times for accumulation in soils & sediments].

Radionuclide	Facility Interest		Technical Issues
	Deep	Shallow	
Sn-126	Y	N	Organic forms and volatilisation External irradiation from Sb daughter Butyl forms (aquatic environment)
I-129	Y	Y	Soil: Plant; Long-term accumulation linked to bio-availability affected by organics in soils and sediments, redox sensitivity, interactions with dead plant material Loss from lake water is not a soil/plant issue, but an Atmospheric/Inhalation pathway issue. Aspersion model parameters Animal products – concern over use of empirical data,
Np-237	Y	Y	Soil to plant to animal } f_1 value, transfer to meat Drinking Water to animals} Need to make information available to assessment community
Uranium Series	Y	Y	High quantities in soil, Long-term accumulation in soil and sediments, external irradiation Soil intake by animals Th isotopes and inhalation Rn-222 – Pb-210 – Plant deposition Aspersion irrigation Resuspension from soils and sediments (activity distribution between suspendable fraction and bulk soil) Aeolian redistribution, following long term irrigation and ash deposition from volcanic eruptions Respiratory and inhalation dosimetry (activity distribution on particles of different size and chemical form) Ra in freshwater fish [part of discussion of why there is an issue.] Pb-210:Po-210 accumulation in aquatic organisms in general.
Pb	Y	Y	Chemo-toxic data, not radio-toxic data required Metallic and sulphate (more mobile) – can have high conc. in cement Main transfer parameter f_w Pb (potatoes, cereals and fruit, aspersion) Based on Pb-210, solubility limit issues Animal pathway also suggested. Issues of flooding and irrigation of pasture. Pb^{2+} and Ca^{2+} analogies in animals
B	Y	Y	Chemo-toxic data not radio-toxic data required. Aspersion, drinking water, mobile, take up by animals – leave in to see how different from radionuclides, however, not very toxic

4 RECOMMENDATIONS FOR FUTURE ACTION

4.1 Working Groups

It is hoped that the exchange of information in Section 2 and identification of the issues in Section 3 is of use in itself. It was suggested that the following Working Groups be set up under the following Theme headings and with the Tasks identified for completion. All these suggestions should be understood within the context of resolving the Key Issues identified, and not more broadly. Other projects with related interests or of possible useful input are identified, with a view to avoiding duplication or leaving gaps in the set of issues to be addressed.

Theme 1: Specialised Data-Base

1. Create database for Key Radionuclides and Process data (initially: Cl-36, Np-237, C-14, U series and B, Pb)
    - Specify the data required (extending the detail in the Table in Section 3)
    - Design and construct the database (there will be a need for extensive comment)
    - Investigate the particular items
    - Populate the database
    - Make suggestions for revised models in light of data quality and/or further experimental and/or monitoring work

Theme 2: Modelling

1. Develop guidance on aspersion modelling
    - Compare current models, identifying differences and why they arise
    - Review and consider adequacy of data
    - Develop guidance for modelling and possible further experimental and/or monitoring work

2. Develop guidance on the inhalation pathway for actinides accumulating in soils/sediments
    - Compare current models, identifying differences and why they arise
    - Review and consider adequacy of data
    - Develop guidance for modelling and possible further experimental and/or monitoring work

3. Review modelling of C-14 behaviour in soil and uptake into crops and develop recommendations relevant in particular circumstances. (May also wish to do this for Cl-36, Tc-99 and I-129, depending on priorities and outcome of work in Theme 1.)

4. Updated Model-Model comparison exercise, as in BIOMOVS II completed 7 years ago, but taking account of site specific issues, regulatory and other developments. A key issue will be modelling long term accumulation. (Note that the BIOMOSA models being developed for sites within Europe could be involved.)

5. Update and review use of analogue data to resolve the key issues identified, including data from monitoring of nuclear facilities and data from natural analogues, including those modified by man. (NB. IAEA CRP)

6. Develop guidance on modelling environmental change
   - Identify changes of interest (NB. BIOMASS Theme 1 Example 3, and BIOCLIM ouput)
   - Develop guidance on how to deal with these changes in describing the system (NB. Note output from BIOCLIM)
   - Identify how to model contaminant migration and exposure under such system change.

7. Develop guidance on modelling transfer of contaminants across the geosphere-biosphere interface zone (GBIZ)
   - Use output from review of analogues (Task 3)
   - Develop list of FEPS to consider for different types of interface
   - Develop guidance on modelling these FEPs for the different types of interface. (NB BIOMASS Example2B, which includes consideration of different types of near-surface interflow within a catchment.)

8. Model-data validation exercise(s), based on applying output from Theme 1 and Tasks 4 and 5 above.

9. Develop suggestions for new experiments and monitoring work, based on the above Task output.

Theme 3: Site Investigation, Experiments and Monitoring

1. Develop guidance on biosphere site specific characterisation: identifying types of measurements to be made, why they are useful and including protocols of how they should be made.

2. Develop protocols for design of research intended to support long term biosphere assessment

3. Review suggestions coming from Themes 1 and 2 for new work.

4.2 Method and Schedule of Work

Not everyone will be interested in everything or will have resources to actively participate in all. It is proposed that BIOPROTA participants become involved in the Themes and Tasks above according to their special interests.

Once the work is organised in detail, the main effort should be carried out by small Task Groups with special expertise in the particular areas. Their output can be reviewed more widely, but it is not the intention to develop an overall consensus, only to check for major errors or omissions.

To reach decisions on Task Group activities, it is proposed to hold a 3 day Workshop in Osteras, near to Oslo, at the invitation of the Norwegian Radiation Protection Authority, in the week beginning 28 October 2002. Material will be prepared in advance for consideration by participants. There may be opportunities to discuss ideas with relevant experts at the conference in Monaco, 1 – 5 September, on Radioactivity in the Environment.

It is assumed that progress and output must be demonstrated according to a clear program. That program can only be fully developed at the Oslo meeting. The rate of progress will depend on the level of effort available from participants. However, from discussion at the current workshop the practical but provisional targets for output in the first year, ending September 2003, can be:

- Theme 1, Task 1: An initial version of the specialised database. Sub-goal, database design and content March 2003.
- Theme 2, Task 1: Aspersion modelling, completed report.
- Theme 2, Task 2: Actinide inhalation exposure modelling, completed report.
- Theme 2, Task 3: Design of Model-Model comparison exercise.
- Theme 2, Task 4: Use of analogue data in biosphere assessment, completed report.
- Theme 2, Task 5: Modelling environmental change, draft report with final awaiting final output from BIOCLIM
- Theme 2, Task 6: GBIZ modelling, draft report with final dependent upon consideration of final report from Task 4.
- Theme 2, Task 7: Model-data validation exercise(s), initial ideas developed for possible application.
- Theme 3, Task 1: Biosphere site specific characterisation guidance, completed report.
- Theme 3, Task 2: Experimental and monitoring research protocols.

Practical suggestions for new experimental and monitoring research may arise at any time. Such suggestions could be taken up within BIOPROTA or by individual organisations, according to priorities and resources available. While a clear set of technical output is suggested above for the first year to September 2003, it is suggested that the BIOPROTA program could continue according to the activities outlined over a period of three years.

5 ACKNOWLEDGEMENT

All participants expressed their thanks to ANDRA for hosting the Workshop and providing excellent facilities and hospitality.

APPENDIX A: BIOPROTA CONCEPT DESCRIPTION, AS AT APRIL 2002

Background

Decisions on releases of radioactivity into the environment rely on a great variety of factors. Important among these is the prospective assessment of radionuclide behaviour in the environment, the associated migration and accumulation among and within specific environmental media, and the resulting environmental and human health impacts. Such assessments have been developed over several decades based on knowledge of the ecosystems involved, as well as monitoring of previous radionuclide releases to the environment, laboratory experiments and other research.

In some cases, problems arise in obtaining good data for these assessments. Particular difficulties arise in the case of long-lived radionuclides, because of the difficulty of setting up relevantly long term monitoring and experimental programmes, and because the biosphere systems themselves will change over the relevant periods, due to natural processes and (or including, if you prefer) the interference of mankind.

It is also the case that, for one reason or another, much radioecological research has focussed on relatively few radionuclides, eg Sr-90 and Cs-137. While this has been relevant, other radionuclides tend to dominate long term impacts as may arise from releases from solid radioactive waste repositories, such as Cl-36, Se-79, Tc-99, Np-237 and others. This is obvious from the results of performance assessments for shallow and deep solid radioactive waste repositories, e.g.:

- the Japan HLW 'H12' assessment;
- the Drigg shallow burial facility post-closure assessment, NRPB-M148;
- the SKB HLW assessment 'SR-97'; and
- papers such as Watkins et al, in the Stockholm Environment Conference of 1998, which describe the key radionuclides in the Yucca Mountain performance assessment in the USA.

Indeed, there are many examples. However, the number of radionuclides involved is relatively small, as is the number of important processes associated with migration and accumulation in the biosphere, and the related radiation exposure of humans and other biota.

In addition, the long term sustainability of radioactive effluent discharges can only be considered in the light of a good understanding of such longer lived radionuclides, even if the discharges are dominated by shorter lived radionuclides.

Several projects have been undertaken internationally to improve the long term assessment basis. Among these, the International Atomic Energy Agency's BIOMASS Theme 1 has provided a clear basis for identifying, justifying and describing biosphere systems. The development of conceptual and mathematical models has been set out and a Protocol developed for the application of data to these models.

Several new international projects have or are being set up which further support long term radiological assessments:

BIOCLIM – helps to define the biosphere systems in response to environmental (climate) change;
FASSET – is developing the technical basis for assessing impact on the environment;
BIOMOSA - more specifically exploits the BIOMASS methodology on a regional specific basis.

BIOPROTA

None of the above projects addresses the uncertainties associated with the key processes for the key radionuclides. BIOPROTA seeks to address those key uncertainties. Participation is aimed at national authorities and agencies with responsibility for achieving safe and acceptable radioactive waste management, both regulators and operators. It is taken as understood that there are radioecological and other data and information issues which are common to specific assessments required in many countries. The mutual support within a commonly focused project would make more efficient use of skills and resources, and provide a transparent and traceable basis for the choices of parameter values as well as the wider interpretation of information used in assessments.

Part at least of the information of interest falls within the discipline of radioecology. Per Strand, of the Norwegian Radiation Protection Authority and General Secretary of the International Union of Radioecology, has suggested provisional objectives and scope for such a project, as well as offering support through IUR membership. The following sets out the suggested objectives and scope, outlines a work program and method of work for the project, and provides an indication of how the project could be coordinated.

Objectives and Scope

- To make available the best sources of information to justify modelling assumptions made within radiological assessments of radioactive waste management. Particular emphasis would 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 project would be 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. Such solutions may readily take account of the BIOMASS Theme 1 Data Protocol, among other things.

- The results of the project could range from relatively precise recommendations on what data to apply to particular assessment situations, to more generic types of information which should be taken into account when making modelling assumptions.

- The modelling assumptions include the treatment of various features, events and processes (FEPS); the mathematical representation of those FEPs and the choice of parameter values to adopt within those mathematical representations.

- The project would be very focused on key data requirements identified by a top down evaluation of assessment requirements, and not be a simple generic compilation of available information. If information required is not available, then the project would use such resources as are available to carry out the relevant research, in a collaborative cost-effective manner, in order to provide that information.

Outline Work Programme and Method of Work

The tasks include:

1. identification of the key information and data issues for radionuclides and processes of common interest;
2. classification of the data needs into areas of common interest;
3. workshops on each area, to determine the best approach/solution to meeting the data requirements;
4. implementation of the workshop recommendations by task groups, etc.

Implementation can take the form of:

- review of existing information (not just review of previous data compilations, but the examination of the original papers and publications) by expert panels and elicitation exercises;
- extension of existing information through the determination of analogous systems;
- recommendations and implementation of new field measurements to better understand the ecosystems,
- recommendations and implementation of new monitoring of radionuclides in the environment, and
- recommendations and implementation on new laboratory experiments.

As noted in the Objectives and Scope, the output should provide the generic basis for adopting particular assessment assumptions in each of the areas of common interest. Given the focus on key processes for key radionuclides, one can see that the work should support the choice of assumptions, avoiding so far as possible unnecessary caution or pessimism.

For example, retention of radionuclides in soil is an important process for some radionuclides. The project would determine for which radionuclides it is actually important, and in what circumstances, then describe the type of information about the soil which is required to make an appropriate assumption for 'k_d', and then provide values associated with relevant example soil characteristics. These suggestions could then be adopted within specific assessments. Alternatively, different assumptions could be adopted if the specific assessment requirements do not exactly match, but the different assumptions would be made taking account of the information requirements identified within BIOPROTA.

As such, BIOPROTA would not prejudice assumptions to be made in specific assessments, but would provide a transparency basis for decisions through a relatively independent project. The results would also provide a justification for not using resources looking for information for combinations of processes and radionuclides which are not important.

Timescale

The project could start in the second quarter of 2002 with an initial work programme designed to produce results within 12 months; but with review at the 6 month stage to determine the scope for a second year of work. The second year would produce results roughly at the same time as outputs from BIOMOSA, FASSET and BIOCLIM. The programme could then be further extended to cover what are bound to be longer term issues relevant to national projects and within OSPAR/SINTRA, etc.

Organisation and Implementation

The model proposed for organising the project is that adopted for BIOMOVS. That is, the project could be managed by a committee made up of representatives of organisations who wish to participate and provide technical and financial support.

The following schedule is suggested as a practical way forward to initiate the project.

- During the summer of 2002, an initial workshop could be held to discuss, identify and prioritise the common problem areas. These could be documented prior to the summer break and distributed to a wider audience, who may have common interest, but who may also be able to provide some part of the solution.

- In September 2 – 5, the IUR, in cooperation with others, is arranging a conference on Radioactivity in the Environment. Many people in the wider audience referred to above will participate. A side meeting at the Conference could be used to promote the Project, further discuss the issues and find people who may be able to solve the problems.

- Thereafter, more specifically focused workshops could be used to consider best approaches to gaps in data, to elicit parameter values, and to develop experimental or monitoring designs, etc.

APPENDIX B: INTERESTED ORGANISATIONS AND WORKSHOP PARTICIPATION LIST

Organisation / Address	Contact Name(s)	Telephone Number	Fax Number	Email address	Attended	Provided presentation/ input
ANDRA Parc de la Croix Blanche 1-7 rue Jean Monnet Chatenay-Malabry F-92298 Cedex France	Elisabeth Leclerc-Cessac Marie-Odile Gallerand Delphine Texier Achim Albrecht	+33 1 4611 8286 +33 1 4611 8041 +33 1 4611 8310 +33 1 4611 8456	+33 1 4611 8208 +33 1 4611 8208 +33 1 4611 8208 +33 1 4611 8208	elisabeth.leclerc@andra.fr MO.Gallerand@andra.fr Delphine.texier@andra.fr Achim.albrecht@andra.fr	YES YES YES YES	YES
ANPA 48 Via Vitaliano Brancati Casella Postale n 2358 00144 Rome Italy	Giuseppe Sedda Mario Dionisi	 +39 065 007 2303		sedda@anpa.it dionisi@anpa.it	YES NO	YES
BNFL R202 Rutherford House Risley Warrington UK	Gavin Thomson Paul Humphreys	+44 1925 833 954 +44 1925 832 654	+44 1925 833 561 +44 1925 833 561	gavin.thomson@bnfl.co.uk paul.n.humphreys@bnfl.com	YES NO	YES
CIEMAT/ DIAE Avenida Compultense 22 28040 Madrid Spain	Paloma Pinedo David Cancio	+34 91 346 6750 +34 91 346 6628	+34 91 346 6121 +34 91 346 6121	paloma.pinedo@ciemat.es David.cancio@ciemat.es	YES YES	YES
ENRESA Calle Emilio Vargas 7 Madrid 28043 Spain	Antonio J.B. Cortes-Ruiz	+34 91 566 8149 +34 91 566 8278	+34 91 5668 165	acor@enresa.es	YES	YES

Organisation / Address	Contact Name(s)	Telephone Number	Fax Number	Email address	Attended	Provided presentation/ input
Institut de Radioprotection et Surete Nucleaire Avenue de la Division Leclerc B P 6 F-92265 Fontenay-aux-Roses Cedex France	Karine Beaugelin-Seiller, Cadarache Pascal Santucci, Cadarache Didier Gay, Fontenay	+33 4 4225 3394 +33 4 4225 7030 +33 1 4654 9158	+33 4 4225 6292 +33 4 4225 6292 +33 1 4654 7727	karine.beaugelin@irsn.fr pascal.santucci@irsn.fr didier.gay@irsn.fr	YES NO NO	
NAGRA Hardstrasse 73 CH-5430 Wettingen Switzerland	Frits van Dorp	+41 56 437 1217	+41 56 437 1317	vandorp@nagra.ch	YES	YES
NIREX UK Nirex Ltd Curie Avenue Harwell, Didcot Oxon OX11 0RH UK	Mike Thorne, contractor to Nirex Paul Degnan	+44 1422 825 890 +44 1235 825 367	+44 1422 825 890 +44 1235 820 560	MikeThorneLtd@aol.com paul.degnan@nirex.co.uk	YES NO	YES YES
Norwegian Radiation Protection Authority PO Box 55 1332 Osteras Norway	Helene Stensrud Per Strand Ingar Amundsen	+47 6716 2537 +47 6716 2564 +47 6716 2539	+47 6714 7407 +47 6714 5444 +47 6714 7407	helene.stensrud@nrpa.no per.strand@nrpa.no ingar.amundsen@nrpa.no	YES NO NO	YES
NUMO 1-23 Shiba 4-Chrome, Minato-ku Tokyo 108-0014 Japan	Morimasa Naito	+81 3 4513 1532	+81 3 4513 1599	mnaito@numo.or.jp	YES	YES

Organisation / Address	Contact Name(s)	Telephone Number	Fax Number	Email address	Attended	Provided presentation/ input
ONDRAF/NIRAS Avenue des Arts 14 BE-1210 Brussels Belgium	Wim Cool Peter Depreter	 +32 2 212 1011 (1049 direct)	 +32 2 218 51 65	w.cool@nirond.be p.depreter@nirond.be	NO NO	YES
Ontario Power Generation 700 University Avenue M5G 1X6 Toronto, Canada	Paul Gierszewski Sean Russell			paul.gierszewski@opg.com sean.russell@opg.com	NO NO	YES
Posiva 27160 Olkiluoto Finland	Ari Ikonen	+358 2 8372 3749	+358 2 8372 3709	ari.ikonen@posiva.fi	YES	YES
QuantiSci Ltd Building D5 Culham Science Centre Abingdon Oxfordshire OX14 3DB UK	Graham Smith	+44 (0)1235 468811	+44 (0)1235 448828	Graham.smith@enviros.com	YES	YES
SKB Box 5864 S-102 40 Stockholm Sweden	Ulrik Kautsky	+46 8 459 8419	+46 8 662 4974	ulrik.kautsky@skb.se	NO	YES
SOGIN	Giorgio Mingrone Angelo Paratore	+39 06 83040463 +39 06 83040463	+39 06 83040482 +39 06 83040482	mingrone@sogin.it paratore.angelo@enel.it	YES NO	

Organisation / Address	Contact Name(s)	Telephone Number	Fax Number	Email address	Attended	Provided presentation/ input
UKAEA Dounreay Thurso Caithness KW14 7TZ, UK	Michael S Tait	44 1847 802 121	+44 1847 802 900	michael.s.tait@ukea.org.uk	NO	YES
US Nuclear Regulatory Commission Office of Nuclear Material Safety and Safeguards 11555 Rockville Pike Rockville Maryland 20850 USA	Christopher McKenney	001 301 415 6663	001 301 415 5399	cam1@nrc.gov	NO	YES
Yucca Mountain Project 1180 Town Center Drive Las Vegas Nevada 89134 USA	Eric Smistad Maryla Wasiolek Anthony Smith Wesley Wu	 +1 702 295 7523 +1 702 295 3016 +1 702 295 4398	 +1 702 295 0438 +1 702 295 0438 +1 702 295 0438	Eric_smistad@notes.ymp.gov maryla_wasiolek@ymp.gov anthony_smith@notes.ymp.gov wesley_wu@ymp.gov	NO NO NO NO	YES

In addition, C-M Larsson of the Swedish Radiation Protection Authority and L Baekelandt of Agence Federale de Controle Nucleaire (FANC), have expressed interest in BIOPROTA and ask to be kept informed.

APPENDIX C: WORKSHOP AGENDA

Wednesday, 12 June

13.00: Introductions, acceptance of agenda
13.15: Reminder of objectives and feedback on interest and participation
13.30: Presentations from participants

ANDRA
BNFL
ENRESA/CIEMAT
NUMO
NAGRA
NIREX
ANPA

17.30 : Close

Thursday, 13 June

09.00 : Continuation of presentations

Posiva
SKB
ONDRAF/NIRAS
Ontario Power Generation
US DOE, Yucca Mountain Project
US NRC
UKAEA

11.00: Round-Table 'Brain-Storm' to identify common issues
13.45: Discussion of options for resolving the issues:

literature survey
previous assessments
shared information
use of analogues
new measurements
new experiments…

Identify what is practicable!

Friday, 14 June

09.00: Summarise Key Issues and Identify Common Key Issues and Themes
10.00: Consider basis for a continuing BIOPROTA project: write up and dissemination of workshop material; interfaces with other projects.
13.00: Close of workshop