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1. **INTRODUCTION**

Models are essential tools for use in the regulatory control of nuclear facilities and activities in planned, existing and emergency exposure situations. Modelling the fate of radionuclides in the environment and assessing the resulting radiation doses to people and the environment is needed, for example, in the evaluation of the radiological relevance of routine and accidental releases of radionuclides, to assist in decision making during remediation activities, in the framework of long-term safety assessments of nuclear waste disposal facilities, as well as for clearance and exemption of material with low levels of radioactivity.

The assessment of radiation doses to humans and impacts on the environment requires the consideration of many factors and their interaction, including the radionuclides involved, environmental conditions, agricultural practices and human life styles. Many model parameters are needed to characterize the specific exposure conditions and to quantify the transfer of radionuclides within an ecosystem. Estimated exposures are associated with uncertainties, since the parameters used to calculate them are subject to a more or less pronounced variability. This is even the case for relatively well defined boundary conditions due to the inherently incomplete knowledge about the exposure conditions.

Radiological impact assessments are necessary to prove compliance with regulatory standards, to support decisions during and after nuclear emergencies and to optimize, for example, the remediation of contaminated sites. In any case, the impact on public health, on public acceptance of decisions and the economy may be considerable.

The IAEA’s Modelling and Data for Radiological Impact Assessment (MODARIA) programme ran from 2012 to 2015. In common with the previous IAEA programmes, Biosphere Modelling and Assessment (BIOMASS), (1996–2002), and EMRAS I (2003–2007), and EMRAS II (2009–2011), it had the following general objectives:

— To improve environmental assessment models and modelling methods through model testing and comparison;
— To harmonize, where appropriate, environmental modelling philosophies, approaches, and parameter values;
— To address the radionuclide transfer in a wide range of environments conditions, including subtropical and tropical regions;
— To provide an international focal point for the exchange of information on environmental assessment modelling;
— To assist Member States in implementing IAEA Safety Standards in the field of control of exposures to the public and the environment.

The MODARIA programme was launched during the first Technical Meeting, which was held in November 2012. MODARIA focused on the following four key areas, which were addressed through ten Working Groups:

— **Remediation of Contaminated Areas**

  Working Group 1 — *Remediation strategies* and decision aiding techniques

  Working Group 2 — Exposures in contaminated *urban environments* and effect of remedial measures
The MODARIA programme concluded during the 4th Technical Meeting, which was held from 9–13 November 2015. All working groups prepared or are currently preparing a report on the objectives, the methodologies and the results of the work done in the framework of the MODARIA programme. All working group reports will be published in the IAEA TECDOC publication series.

After the conclusion of the MODARIA programme the IAEA decided to continue such model testing and comparison activities by setting up the follow-up programme MODARIA II: Modelling and Data for Radiological Impact Assessments. The MODARIA II programme was launched at a Technical Meeting held at the IAEA’s Headquarters in Vienna, Austria, from 31 October to 4 November 2016.

The MODARIA II programme was set up to address the following needs:

— The revised Basic Safety Standards (BSS)\(^1\) have been approved by the IAEA’s Member States by all co-sponsoring international organizations, i.e. the Food and Agriculture Organization of the United Nations (FAO), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the United Nations Environment Programme (UNEP) and the World Health Organization (WHO).

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— The IAEA developed safety guides in the field of protection of the public and the environment to assist Member States in implementing the related safety requirements regarding exposures to the public in planned, existing and emergency exposure situations, as well as regarding radiological impacts to the environment. MODARIA II will continue to address these activities.

— International exercises to develop and improve environmental assessment models are well appreciated. The IAEA Action Plan on Nuclear Safety recommends strengthening Member States’ capabilities for the assessment of exposures to the public and radiological impacts to the environment.

— The International Expert Meetings “Decommissioning and Remediation after a Nuclear Accident”, “Meeting on Assessment and Prognosis in Response to a Nuclear or Radiological Emergency”, “Radiation Protection after the Fukushima Daiichi Accident - Promoting Confidence and Understanding” – organized by the IAEA after the Fukushima Accident – have highlighted the importance of reliable assessments of doses to the public for decision making and communication.

— Member States across the world need to manage residues containing enhanced levels of natural radioactivity produced during industrial activities or during mining of metals and uranium.

— The implementation of nuclear power programmes in Member States require comprehensive capabilities for assessing radiological impacts arising from discharges of radionuclides into the environment.

The ability of the MODARIA programme to act as an international focal point for environmental modelling issues was very much appreciated by the programme’s participants. Furthermore, such activities provide support which helps to compensate for the potential loss of knowledge and competence in the areas of radioecology and environmental assessment.

In order to identify the interests and needs of potential participants, a special plenary session was held during the last Technical Meeting of MODARIA I, which provided participants the possibility to present and discuss proposals for a follow-up programme. Seventeen proposals were submitted. These proposals were discussed under the broad headings:

— **Remediation and decision making**
  Safety assessment for NORM and legacy sites to support remediation
  A method for monitoring spatial distributions of radionuclides at legacy sites
  Decision making in existing exposure situations

— **Exposures in urban environments following accidents**
  Exposure to people in aircrafts when passing contaminated air masses
  Validation of atmospheric dispersion models applied after short-term releases of radionuclides
  Assessing exposures to people in contaminated urban environments

— **Modelling releases to the environment**
  Integrated assessment of exposures to humans and biota for routine discharges
  Environmental models and model parameters for tropical environments
Exposures to people following accidental tritium releases

— **Radioecological data**

Time-dependent environmental transfer parameters determined in Japan after the accident in the Fukushima NPP

Development of a data base for sorption coefficients (Kd)

— **Exposure and effects to wild-life**

Modelling radiation effects on populations of wildlife species

Modelling radiation exposures to biota

— **Biosphere modelling for long-term safety assessments of waste disposal facilities**

Climate change and landscape development in the context of long-term assessment

Review and enhancement of IAEA-BIOMASS-6 (2003) Reference Biospheres Methodology

— **Marine modelling**

Modelling the transfer and fate of radionuclides following short-term releases to marine systems

To analyse the proposals in view of the Member States needs to implement the IAEA safety standards, to develop assessment capabilities, and to ensure appropriate control of exposures to the public, the IAEA secretariat organized a consultants’ meeting in the IAEA headquarters in Vienna from 29 February to 2 March 2016.

**1.1. Proposals for MODARIA II Working Groups**

Based on the proposals made and the need to facilitate the implementation of the radiation protection requirements set out in the revised BSS regarding exposures to the public in planned, existing and emergency exposure situations and radiological impacts, proposals for the MODARIA II programme were elaborated. Work programmes for the following topics were developed:

— Remediation and decision making.
— Exposures in urban and rural environments following accidents
— Modelling radionuclide releases to the environment:
— Analysis and evaluation of radioecological data, including radionuclide transfer in tropical and sub-tropical environments
— Radiation exposures and effects on wildlife;
— Biosphere modelling for long-term safety assessments of waste disposal facilities;
— Marine modelling.

The proposals are described in detail in the following section and will be presented and discussed in full during the first MODARIA II Technical Meeting, during which participants are invited to present any further proposals regarding the Working Groups.
2. WORKING GROUPS

2.1. Working Group 1 — Assessment and Decision Making of Existing Exposure Situations for NORM and Nuclear Legacy Sites

2.1.1. Background

Environmental remediation of NORM and legacy waste sites normally involves four main activities: (a) initial site characterization and selection of remediation criteria; (b) identification of remediation options and their optimization, followed by subsequent development and approval of the remediation plan; (c) implementation of the remediation plan; and (d) post-remediation management. Following the completion of each of these main activities, a decision should be made about whether to release the site (or part of it) for either restricted or unrestricted use, or to proceed to the next activity (IAEA W-SG-3.1 and DS468: Remediation Process for Areas with Residual Radioactive Material). Similar assessment and decision processes also apply to activities involving in-situ decontamination and decommissioning of nuclear facilities.

Traditionally, assessments of radionuclide transport/transfer in the environment and effects of radionuclide exposure on human health and the environment are performed to demonstrate compliance with regulatory requirements. Such radiological environmental impact assessments are often needed to characterize the existing contamination condition or to minimize undesirable radiological impacts of proposed remedial measures on humans or the environment in compliance of regulatory requirements, within the context of an overall risk assessment. Results of risk assessments provide one key input to environmental management decisions for NORM or nuclear legacy sites. In recent years, decision making for low- and intermediate-level waste at NORM and legacy sites is moving towards using a risk-informed, performance-based approach. Decision analyses that also take into account other contributing factors (e.g., economic constraints, stakeholder preferences, etc.) are increasingly being used to aid decisions that aim at addressing waste management issues in a holistic manner, to achieve the optimum solution for disposal, closure and long-term management.

Risk assessment and decision analysis are interconnected activities: the risk assessment provides toolsets and risk information that are a central input to decision making, where the decision analysis can identify the specific needs and guide the selection of exposure scenarios for conducting the risk assessment, or can be used as part of justification and optimization in selecting feasible remedial options.

This Working Group will develop methodologies and toolsets for assessing radiological impacts and aiding decisions for safe remediation and management of NORM or legacy sites in the short- and long-term. These risk assessments and decision analyses will need to address the following questions:

— Do associated risks justify remedial measures?
— What are the preferred/optimal remedial options?

2 i.e., those that are affected by contaminated residues from, for example, the mining industry (uranium, metals, etc.), the phosphate industry, or past nuclear research or production activities
— Can it be demonstrated that the preferred remedial option can be safely implemented?
— Can long term safety be demonstrated?
— In addition to risks associated with radiological safety, what other factors will drive remedial decisions and how can this be evaluated?
— How can an optimum decision be made in managing the particular contamination situation, considering all the contributing factors?

2.1.2. Objectives of the Working Group

The main objective of this Working Group is to further develop radionuclide transport and exposure models and radiological impact assessment approaches that can be applied to support decision making for the remediation of NORM and legacy sites. To build confidence in these exposure assessments, the Working Group will also conduct model comparisons using monitoring data, where available.

Additionally, the objectives of this Working Group also include further development of methodologies and toolsets for conducting decision analyses that aid in decision making.

Risk Assessment Objectives
— Apply modelling methodologies and tools to existing NORM and legacy sites and facilities, considering regulatory requirements
— Perform assessments for relevant regulatory endpoints
— Test safety assessment models against monitoring results
— Develop assessment protocols
— Develop visualization of spatial radionuclide distributions and as input to impact assessment
— Train end users (regulators, operators, other stakeholders) in the use of the risk assessment methodologies.

Decision Analysis Objectives
— Identify types of information required to support decision processes
— Define “prevailing circumstances” for site specific situations
— Evaluate arguments for supporting decisions
— Explore the non-nuclear industry for additional methods, examples and experience
— Explore different types of remedial options and their effectiveness in blocking/impeding exposure pathways and dose reduction

2.1.3. Tasks of the Working Group

The following tasks will be carried out in parallel by the Risk Assessment and Decision Analysis Subgroups. Joint sessions/meetings are encouraged to promote technical exchange and feedback between the subgroups. These joint activities will benefit from, amongst other things, the identification of overall project needs, the selection of scenarios for analyses, and the effectiveness in communicating modelling results.
**Risk Assessment Tasks**

The Risk Assessment Subgroup will continue to further develop modelling methodologies and tools from MODARIA I, perform model comparison and validation to build model confidence, and apply the models to existing legacy sites and facilities – considering regulatory requirements:

— **Development of methodology for radiological impact assessments**: The Working Group could develop detailed recommendations on how to perform radiological impact assessments in support of decision making for the remediation of radioactively contaminated land in accordance with relevant IAEA safety standards. The methodology developed by this Working Group will be used as a starting point and will be expanded to provide more specific and detailed recommendations for typical situations where the necessity of remediating NORM and radioactively contaminated legacy sites is to be explored and/or the remediation of such sites is required. In MODARIA II, the methodology will be further refined with additional FEP analyses, updated screening tools, and improved databases. The WG will develop a FEP list for mining and other NORM facilities and activities and will derive relevant scenarios.

— **Improvements to assessment models included in NORMALYSA**: The code could be improved to incorporate new submodels for source terms, seasonal effects, integrated flow and transport models, and parameter values for different situations. Additional radionuclides or other chemicals of concern may also be incorporated, if warranted.

— **Performance of model–model and model–data comparisons**: For selected scenarios of relevance, model–model and model–data comparisons will be carried out to build confidence in models to be used for exposure assessments. Some of the scenarios will be provided at the start of the programme, whilst others will be developed by the Working Group during the course of MODARIA II. The screening models developed or reviewed by the Working Group in MODARIA I (RESRAD, HYDRUS, the ERICA Tool) will be used by the participants for these comparisons. As part of this effort, the Working Group will conduct sensitivity and uncertainty analyses in collaboration with WG3.

— **Application to existing sites and facilities**: Set up and perform case studies by operators and regulators – integrating with decision making methodologies developed in the Decision Making Subgroup.

— **Visualization of spatial radionuclide distributions at the Andreeva Bay SNF temporary storage facility in Russia**: Integration of a device (e.g., Rucksack) for walking surveys for gamma-dose-rate measurements. Testing the use of a tool to visualize the distribution of gamma-dose rates in support of the assessment and/or licensing processes.

— Training of end users (regulators, operators, other stakeholders) on use of NORMALYSA: Hands on training during WG meetings.

**Decision Analysis Tasks**

The Decision Analysis Subgroup could perform the following tasks:

— **Develop lists of “prevailing circumstances” and site specific situations**: The lists will be developed by categorizing by facility and origin of contamination. Consideration will be given to the required quality of arguments in different scenarios, as well as the need for stakeholder engagement. The lists will be the outcome of balancing competing risks and other factors, and if necessary, resolving conflicts between risk considerations and other
decision factors. An effort will be made to bring experience from non-nuclear industry into IAEA guidance (e.g. on stakeholder engagement and conflict resolution), while balancing other decision factors. Specifically, the subgroup will review experience to develop lists (e.g., existing case studies, other IAEA documents, literature review), and survey best practices in other industries, such as mining, oil/gas, chemical, cross-cultural decision making in the construction industry, stakeholder mapping, and soft modelling/problem formulation.

— **Develop methodologies and toolsets for formalized decision analysis:** This Working Group will conduct literature reviews to build on the work of MODARIA I and to start developing methodologies and toolsets for formalized decision analyses using e.g., the Bayesian approach, to support a risk-informed, robust decision making process for managing NORM and legacy sites. The methodologies will need to: actively involve stakeholders; clearly define the decision analysis by identifying objectives, decision options, and events; and effectively communicate judgements about costs and values, uncertainty, and risks. Particular attention should be given to integrating the decision analysis methodologies and toolsets with the existing framework for assessments of radionuclide transport models and exposure risk.

### 2.1.4. Expected Outcomes

The Working Group could produce the following results:

— Upgraded methodologies and modelling tools for radiological impact assessments that are internationally consistent;

— Protocols for model verifications that help build confidence in radiological impact assessments;

— Reports from model application to realistic site situations for selected reference cases that represent typical NORM and legacy contamination situations;

— Improved decision making processes as context for technical modelling, for the broader (non-technical) decision context;

— Checklists and TECDOC to guide Member States through the decision making processes including involvement of the public;

— Recommendations on communication and engagement with relevant interested parties;

— Recommendations for methodologies for decision analyses in support of remediation and closure of NORM and legacy sites; and

— Training materials for self-study and/or use in classroom training on radiological impact assessments. Trained end users for the use of the NORMALYSA software.

### 2.1.5. Summary of the first meeting of the Group

The first meeting of Working Group 1 (WG1) was held during the First MODARIA II Technical Meeting. A total of 12 full time participants and 15 part-time/guest participants representing 13 Member States attended this meeting. It was agreed that the new Working Group 1 would conduct its activities in a joint group. The decision-making needs will inform the scope of risk assessments, and the risk insights and structured decision analyses will aid in informed decisions. The group may evaluate the need for forming subgroups to focus on specific tasks at a later time. A preliminary work plan with task assignments and interim
milestones was developed on 4 November 2016. The work will focus on developing methods and toolsets for risk-informed decision-making for NORM and nuclear legacy sites, including case studies for the following sites: (1) the Tessenderlo, Belgium phosphate processing site; (2) the Pridneprovsky, Ukraine legacy site; (3) Los Alamos National Laboratory (LANL), USA Material Disposal Area (MDA) B; and (4) a NORM/legacy site in China that is yet to be determined. The preliminary task assignments were made following group discussions between 31 October and 4 November 2016. Several near-term actions and deliverables were identified, including:

— Provide the draft report from MODARIA I WG3 (Rodolfo Avila);
— Provide the draft report from MODARIA I WG1 (Tamara Yankovich);
— Contact Haruko Wainwright and Paul Black about participation in WG1 (Ming Zhu);
— Distribute presentations from the P&RA CoP Technical Exchange Meeting (Ming Zhu);
— Select the site in China and provide a summary of site conditions (Yunxuan Liao);
— Provide IAEA training materials on NORMALYSA and RESRAD (Rodolfo Avila, Tamara Yankovich);
— Document the decision-making process for lessons learned for the LANL MDA-B land transfer, the mine Zirovskivrh, Slovenia closure, and the Beaverlodge site closure (Jeff Whicker, Amanda Anderson, Branko Kontic, and Stacey Fernandes); and
— Draft a list of contributing factors to be considered in decisional analysis (Adrian Punt).

2.1.6. Work performed in 2017

The 2017 Interim Meeting of MODARIA II Working Group 1 (WG1) was held at the Belgium Nuclear Research Centre (SCK•CEN) in Brussels, Belgium, 27–30 June 2017. The meeting was attended by a total of 27 participants and 1 guest representing 13 Member States. An optional field trip to the Tessenderlo Chemie (TCH) site was organized on 26 June 2017, in which a subgroup of 17 participants participated. The group also visited the Kepkensberg disposal site and remediation works along the Winterbeek River. The main objectives of the meeting were to discuss and update the work plan for WG1 including: (1) review of the frameworks for risk-informed decision analysis using risk assessment; (2) review of current methodologies and toolsets for risk assessment and decision analysis; (3) identification of sites for case studies; and (4) establishment of sub-teams for follow-on work.

A total of 11 sessions were organized to cover the objectives, with an emphasis on the selection of sites for case studies and risk-informed decision making for decisions pertaining to each of these sites. Topics discussed included: a review of frameworks for risk-informed decision analysis; description of sites for case studies; a joint session with WG5; updates on relevant IAEA safety guidance; a discussion of available information on the decision making process and lessons learned; a review of current methodologies and toolsets for decision analyses and risk assessments; discussion of additional sites and modelling studies for consideration by WG1; and discussion of the path forward regarding WG1 activities and the preparation of the working draft of the WG1 final report.

WG1 participants and a subgroup of WG5 members held a joint session on 28 June 2017. Mr Nick Beresford (Joint Leader of WG5) presented a summary of the WG5 case studies, and the expressed interest in joining WG1 for modelling testing. Although the sites currently selected for WG1 case studies do not feature ecological impact assessment, it was agreed that both
groups would continue to evaluate the needs and availability of data sets for conducting biota modelling. Should such needs arise, then Mr Beresford’s team would contribute to the setup and conduct of such work as part of WG1’s case studies.

The WG1 participants agreed to the following action items:

(1) The Tessenderlo Phosphate Processing (TCH) Site, Tessenderlo in Belgium and the Pridneprovsky Uranium Legacy Site in the Ukraine were selected for case studies.

(2) The Los Alamos National Laboratory Site (LANL), Material Disposal Area B in the USA and the Beaverlodge Uranium Mill and Tailings Site in Canada were selected for sharing good practices and lessons learned in risk-informed decision-making for environmental remediation and land conveyance.

(3) An additional site for tin processing in Brazil and possibly another NORM site in China will be evaluated for addition to the case studies during the Second MODARIA II Technical Meeting (TM2).

(4) A working draft of the WG1 final report will be prepared to document the WG1 discussions and analyses in the next year or so. An outline of Table of Contents has been prepared during the IM1.

(5) Initial assignments have been discussed for IM1 participants to collect data, conduct modelling and analyses, and prepare draft sections for the WG1 final report. Other WG1 members who did not attend IM1 are invited to join the efforts if they are interested in doing so.

(6) For the TCH Site, some modelling work was performed by MODARIA I WG3 using NORMALYSA and RESRAD-Offsite during the MODARIA I Programme (2012–2015). The model-model comparisons will be improved as part of MODARIA II. The calculations for Scenario 2A will be redone assuming the same initial conditions. Other codes, such as GOLDSIM and the DCC Calculator, will be used for comparison purposes. In addition, radionuclide transport in the Winterbeek River will be assessed using PC CREAM and NORMALYSA. Biosphere exposure assessment will be conducted using BIOSPHERE, GOLDSIM, NORMALYSA, and RESRAD. Existing datasets will be compiled and evaluated for potential biota dose assessments. The possibility for demonstrating the use of the Guided Interactive Statistical Decision Tools (GiSdT) will be evaluated, considering different risk drivers (Cd, radionuclides, etc).

(7) For the Pridneprovsky Site, additional transport modelling will be conducted using REARAD, GOLDSIM, and the DCC Calculator. Model-model comparison will be performed between these codes and NORMALYSA. Geochemical data will be evaluated for parameter selection. Other potential risks associated with remediation (e.g. worker exposure, transportation, etc.) will be considered, applying the principles of justification and optimization. Radionuclide transport in the Konoplyanka River will be evaluated using PC CREAM, and compared to predictions generated using NORMALYSA. Biosphere exposure assessment will be conducted using BIOSPHERE, GOLDSIM, NORMALYSA, and RESRAD. Existing datasets will be compiled and evaluated for potential biota dose assessments. A general risk-informed decision making framework will be developed with stakeholder engagement.

(8) So far, remediation decisions at the TCH Site have been driven by concerns about chemical hazards (particularly, contamination by cadmium) instead of radiological impact. Issues have been identified to reconcile results from chemical risk assessments and radiological impact assessments. The group proposes to evaluate methodologies to
synchronize analyses of radiological impacts and chemical hazards for the purpose of integrated risk assessment (i.e. dose vs. risk).

(9) One focus area of study is to use integrated models to help develop cost-effective strategies for long term monitoring and to define the end state or exit strategy for remediation sites. Issues faced in designing remediation strategies, with consideration of monitoring needs (e.g. passive vs intensive, sampling locations, depths, frequency, analytes, etc.) will be considered. Draft UK guidance on end state definition will be shared with WG1 members when available.

(10) Options for demonstrating the use of GiSdT for stakeholder-engaged structured decision making at upcoming TM2 will be evaluated.

(11) A joint session with WG3 will be considered for the upcoming TM2 to discuss integration/harmonization with activities concerning human and biota modelling. Follow-up discussions with WG6 on the Features, Events and Processes (FEPs) list and WG2 on urban scenarios are also planned for TM2.

(12) Prior to or during the TM2, Mr Graham Smith will discuss integration/harmonization of WG1 activities with those of ICRP Task Group 98, and Ms Yankovich and Mr David Copplestone will discuss areas of mutual interest between WG1 and ICRP Task Group 105.

2.2. Working Group 2 – Assessment of exposures and doses plus effectiveness of countermeasures in urban environments

2.2.1. Background

Following a nuclear accident, external exposure from radionuclides deposited on the ground is a key exposure pathway in both the short and long term; external exposure from radionuclides in the cloud and internal exposure from inhalation are also important in the short term while the release is continuing. Other contamination scenarios could result from accidental dispersion of radioactive sources.

In urban environments, the exposure situations are very complex due to the interaction of dispersion deposition on different surfaces and exposure geometry. The shielding effects of buildings are important in reducing exposures and can vary considerably depending on the type of building. In MODARIA I, Working Group 2 carried out a number of exercises to test models against experimental or environmental monitoring data to provide insight into the uncertainty associated with models for use in predicting the dispersion, deposition and long term behaviour of radionuclides released into an urban environment.

An important aspect of the work is the effectiveness of countermeasures that can be taken to reduce exposures following contamination of urban environments. The work of this group is of relevance to Working Group 1 (Assessment and decision making of existing exposure situations for NORM and nuclear legacy sites.) In addition, it would be useful if Working Group 2 could interact with the tritium sub-group within Working Group 3 to make use of tritium data for testing of atmospheric models.

2.2.2. Objectives of the Working Group

— To analyse the experience in Japan following the accident at the Fukushima Daiichi nuclear site, including carrying out a remediation exercise using a set of monitoring data.
— To review or develop specific areas of urban modelling, in particular the non-heterogeneous nature of the deposition of radionuclides with accumulation in ‘hotspots’ and the transfer of radionuclides to sewer systems.

— To investigate the limitations and possibilities for atmospheric dispersion in urban environments for both releases in an urban environment and a release outside an urban environment.

— To develop a standardized test case for different designs of nuclear reactors and to estimate deposition.

2.2.3. Tasks of the Working Group

The following tasks could be carried out:

— Further development of the exercises carried out in MODARIA I including:

— Carry out an atmospheric dispersion exercise based on a new data set for Sostanj, which could enable modellers to consider the effectiveness of 3D models and the use of forecasts of meteorological data.

— Carry out a model comparison for a hypothetical situation involving a release into an urban environment (Boletice).

— Carry out a modelling exercise to investigate the need for remediation at specific locations in Japan using data obtained following the Fukushima accident.

— Consideration of possible new areas of urban modelling including:

— The transfer of radionuclides to sewer systems and resulting exposures.

— Review of the possible radiological impact of aircraft flying through a radioactive plume from an unplanned release.

— Dispersion and deposition indoors and the relative importance of indoor and outdoor contamination.

— Initial retention and weathering of radionuclides deposited on urban surfaces

— The shielding effects of different building types.

2.2.4. Expected outcomes

— Improvement of urban modelling capabilities, particularly for the dispersion and redistribution of radionuclides in an urban environment.

— Improvement in the knowledge of the effectiveness and impact of remedial measures for urban environments.

2.2.5. First meeting of the group

The first meeting of WG2 took place at IAEA Headquarters in Vienna during the First Technical Meeting of the MODARIA II Programme; 27 participants from 20 countries attended the meeting. The main objectives of the meeting were to discuss the major WG2 activities that were proposed and to make initial plans for conducting these activities. In addition, WG2 had brief joint sessions with WG3 (WG on Planned Exposure Situations) and
WG1 (WG on Existing Exposure Situations). The main outcomes of the meeting are described below.

**Continuation of a review of models for assessment of public exposures from acute releases**

During the MODARIA I Programme, a review and comparison was carried out of models (computer codes) for predicting transport of radioactive contaminants to urban environments, especially atmospheric dispersion, deposition and environmental transport for situations, such as an accident at a nuclear power plant. The review includes key models currently in use (or still named in national regulations), their functionalities and requirements (computational and in terms of necessary input data), intended uses and other important features. The intent was not to provide an evaluation of which model is “best”, but to provide information that can help users to select the most appropriate models for their own situations. The format is an Excel® workbook with a separate page (worksheet) for each model and a table comparing major features or attributes of all the included models.

During this meeting, WG2 members expressed interest in adding additional models to the collection during the MODARIA II Programme and updating descriptions of some of the models already in the compilation. The latest version of the workbook (July 2016) contains information on 26 models and will be made available on WG2’s secure web folder, and updated versions of the workbook will be made available as information is added.

**Development of a new modelling exercise applicable to contaminant transport inside an urban area**

Two “short range” atmospheric transport exercises, based on field tests from the Czech Republic, were carried out during the EMRAS II and MODARIA I Programmes. At the end of the MODARIA I Programme, P. Kuca and J. Helebrant presented a new scenario based on a field test undertaken at a different location (Boletice, Czech Republic). The field test involved dispersal of a radioisotope by a small explosion and measurement of a number of parameters and endpoints. This field test used a longer lived radioisotope ($^{140}$La) than the earlier tests ($^{99m}$Tc), allowing for a greater number of measurements to be obtained over a greater distance from the dispersion site. Background information will be prepared by P. Kuca and J. Helebrant. Participants in the exercise will be asked to predict deposition (Bq m$^{-2}$) on a defined grid, both for model intercomparison and for comparison with measurements. Other modelling endpoints are also possible.

**Development of a new urban dispersion exercise**

During the MODARIA I Programme, two participants (H. Walter and L. Patryl) presented a preliminary analysis of their results of applying national decision-support models to a hypothetical dispersion scenario based in a major city. The scenario provided useful information about the importance of buildings and street canyons. L. Patryl will begin development of a new urban dispersion exercise to be carried out during MODARIA II.

**Continuation of a modelling exercise applicable to contaminant transport to urban areas from an external location**

Modelling of contaminant transport to urban areas from an external location is applicable to situations such as nuclear power plant accidents (e.g. in the context of emergency preparedness), in which contamination from an accident site could be transported to urban areas. During the MODARIA I Programme, an exercise was developed based on the Šoštanj Thermal Power Plant in Slovenia, a situation with complex terrain and meteorology. Tracer
data (air concentrations) from a 3 week measuring campaign in 1991 are available to validate model predictions for selected locations. For other endpoints (e.g. additional locations, deposition at any location), it is a model intercomparison exercise. Two cases from the data set were used for the modelling exercise during the MODARIA I Programme, including a time period with stable wind conditions and a time period with complex meteorological conditions.

Additional cases from the data set are proposed for use during the MODARIA II Programme. These would involve different release and meteorological conditions than the first two cases. In addition, participants hope to expand the modelling efforts to incorporate 3-D models and meteorological forecasting. M. Boznar and P. Mlakar agreed to prepare further information for discussion at the 2017 WG2 Interim Meeting.

Development of at least one new exercise applicable to contaminant transport to urban areas from an external location

WG2 and WG3 had a joint session to discuss a possible atmospheric dispersion exercise based on measurements of $^{41}$Ar from a Canadian research reactor. Available measurements include emissions and downwind monitoring data, plus meteorological data. V. Korolevych of WG3 described the available data and plans to prepare an initial modelling exercise. Participants in both Working Groups expressed interest in making model calculations for the exercise.

Continuation of a modelling exercise applicable to redistribution and remediation of urban contamination

A modelling exercise focused specifically on urban contamination and remediation was developed by S. Takahara during the MODARIA I Programme, based on monitoring data in an area of Japan evacuated following the Fukushima accident and on information about experimental decontamination efforts and people's behavioural patterns. For MODARIA II WG2 plans to involve additional participants and to expand the scenario to include comparison of measured and modelled (assessed) doses and the predicted effects of decontamination efforts on reducing exposures and doses.

Reviews of literature on topics of importance to modelling urban contamination

Several topics relevant to urban contamination have not been well explored during previous programmes. These topics include sewer systems (transfer to and dispersion within sewer systems, exposures to humans from contamination in sewer systems), various building materials and urban surfaces (e.g. retention in or on, transport in, and weathering from surfaces such as concrete and asphalt; relevant remediation approaches), and indoor contamination (penetration into buildings, dispersion and deposition indoors, remediation of indoor surfaces). Participants in WG2 have expressed interest in addressing some of these topics in the form of literature reviews. At present, E. Sim expects to carry out a literature review of information on the interactions of radionuclides with urban surfaces for her organization and has offered to share the results of that effort with WG2. C. Burdidge has offered to organize a literature review of information on sewer systems, and N. Kwamena plans to contribute. Additional participants are welcome to assist in these efforts, contribute literature that they are aware of, or organize reviews for additional topics. For the literature reviews, the emphasis will be on existing approaches and codes for modelling these systems or situations, information available for parameterizing the models, gaps in the available information, and possible experimental approaches toward filling those gaps.
**Other activities**

WG2 had a brief joint session with WG1 to discuss possible areas of mutual interest between the two groups. Both Working Groups deal with remediation, for example. No specific plans have been made, but the two WGs will keep in contact.

WG2 briefly discussed the possibility of proposing an atmospheric dispersion experiment or related research project. The Working Group can at least assemble some information on what would be needed for a useful experiment and perhaps prepare a proposal. More discussion is planned.

### 2.2.6. Work performed in 2017

The 2017 Interim Meeting of WG2 took place 22–24 May 2017 at IAEA Headquarters in Vienna; 16 participants from 14 countries attended the meeting.

The main objectives of the meeting were to discuss the major WG2 activities that were planned at the First WG2 meeting in 2016, to report progress, and to make further plans for continuing these activities. The activities are described below.

**Continuation of a review of models for assessment of public exposures from acute releases**

Four additional models from the USA have been added to the collection since the First MODARIA II Technical Meeting took place in 2016; these models are used for calculating external exposures, either indoors (BDCC and BRPG) or outdoors (SDCC and SPRG). In addition, several WG2 members have expressed interest in adding additional models to the collection during the MODARIA II Programme and updating descriptions of some of the models already in the compilation.

**Development of a new modelling exercise applicable to radionuclide transport inside an urban area**

Mr Petr Kuca and Mr Jan Helebrant presented a new modelling scenario based on a field test undertaken at Boletice in the Czech Republic. Scenario information, including videos, 3-D models and meteorological data, was made available to WG2 participants. At least 3 or 4 participants are expected to do calculations for this exercise. Initial calculations are requested by the end of September, for discussion during the next meeting of WG2.

**Development of a new urban dispersion exercise**

Mr Luc Patryl presented plans for a new urban dispersion exercise to be carried out during MODARIA II. Four hypothetical scenarios are planned, ranging from a very simple scenario with one building to a realistic scenario based on a real city, possibly using some historical experimental data. All scenarios would use the same source term, release information, meteorology and defined receptor locations. This will permit comparison of predictions for the different scenarios in terms of the complexity of the building arrangements and the effects of the buildings on the dispersion of the radionuclide.

**Continuation of a modelling exercise applicable to contaminant transport to urban areas from an external location**

Ms Marija Boznar and Mr Primoz Mlakar will prepare a third case study from the dataset for discussion during the next WG2 meeting. This case study will involve release and meteorological conditions intermediate in complexity between the two cases considered...
during the MODARIA I Programme. The two earlier cases remain available for modelling by new participants in the group. Ms Boznar and Mr Mlakar also discussed the incorporation of meteorological forecasting into their atmospheric dispersion modelling. At least two, and perhaps as many as five, participants are planning to do calculations for this exercise.

Development of at least one new exercise applicable to radionuclide transport to urban areas from an external location

Since the first meeting, Mr Korolevych has obtained permission to share the dataset, and he plans to select a suitable episode and prepare a modelling exercise in time for the next meeting.

Continuation of a modelling exercise applicable to redistribution and remediation of radionuclides in an urban environment

Mr Takahara presented plans for continuation of this exercise, with several specific goals, i.e. comparison of predictions and measurements for external doses to individuals; comparison of probabilistic and deterministic approaches to dose assessment; and comparison of model predictions with respect to shielding effects and contributions to dose from individual contaminated surfaces.

Reviews of literature on topics of importance to modelling radioactivity in urban environments

Mr Christopher Burbidge presented plans for a literature review of information on modelling releases of radionuclides into sewer systems and the consequent dispersal of radioactivity within the sewer system and releases from the sewer system. The review will include potential exposure pathways and dose assessments related to releases of radionuclides to sewer systems. Additional participants have expressed interest in contributing to this review or to reviews of other topics related to radiological contamination in urban environments. Further discussion of these other topics is planned for the next meeting.

2.3. Working Group 3 – Assessments and control of exposures to public and biota for planned releases to the environment

2.3.1. Background

It is recognized that assessments of exposure and dose from planned releases of radionuclides to the environment would benefit from an integrated approach to modelling for humans and biota, and would facilitate consistent comparisons and better informed decision making. In addition, studies on exposures from radionuclides such as tritium, carbon-14 and radon, and their proper incorporation in the models, would improve the representativeness of the models and enhance our understanding of the importance of these radionuclides.

With regard to the beneficial applications of radiation and radioactive substances, ranging from power generation to uses in medicine, industry and agriculture, the International Basic Safety Standards issued by the IAEA in 2014 states that “radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled”. In addition, the conventional belief that the standards of environmental control needed to protect the general public would ensure that other species were not put at risk, has progressed to an international trend indicating the need to be able to demonstrate (rather than to assume) that the environment is being protected. In order to
provide the international community with practical guidance on these aspects, the IAEA is developing several documents (DS427, DS442, DS432 and the revised SRS19).

Demonstrating that the environment is being protected is usually accomplished by means of a prospective radiological environmental assessment to identify impacts on the environment, to define the appropriate criteria for protection of the environment, to assess the impacts and to compare the expected results of the available options for protection. National and international frameworks exist for the practical implementation of the explicit demonstration of the protection of the environment against ionizing radiations and several methodologies and codes already incorporate some or all aspects of this framework (e.g., CROM8, CROMERICA, RESRAD biota, ERICA tool) and others are being developed.

A logical next step in the MODARIA II project is to identify methods and tools for carrying out integrated radiological assessments for humans and the environment (biota), in order to contribute to the development of reliable guidance for both assessors and decision makers. The integrated approach is intended to also place focus on radionuclides of particular interest in dose assessments such as tritium, carbon-14 and radon.

The behaviour of tritium in the environment is the result of the complex interaction of many processes that are subject to annual, daily and even hourly variations, which inherently cause uncertainties in related predictions. The understanding of these processes was improved during previous IAEA model testing and comparison programmes, however, more work is needed to enable reliable assessments of exposures related to routine accidental tritium releases taking into account actual site-specific conditions. In MODARIA I, these topics were elaborated in Working Group 7.

Working Group 3 in the MODARIA II project is a continuation of the work performed by the Working Groups 5 and 7 in the MODARIA I programme. New aspects of Working Group 3 are considerations of the importance and particularities of carbon-14 and radon in the assessments of exposure and dose for planned releases to the environment. It is also recognized that Working Group 3 will benefit from interactions with the radioecologists in Working Group 4 in the MODAIRA II project.

2.3.2. Objectives of the Working Group

The main objective of this Working Group is to develop and apply an integrated approach to studying the impact of releases to the environment resulting from the applications of radionuclides in energy generation, medicine, research and industry on both humans and biota from ionizing radiation. This group will also explore in which cases typically there is a need for an explicit assessment of the protection of biota from exposures to planned releases of radionuclides and when this assessment is not necessary, due to the expected trivial radiological effects. It is important that tritium, carbon-14 and radon are included in the integrated approach.

As a sub-task, the modelling of tritium characteristics after short-term releases will be performed, with focus on identified aspects of tritium transfer not yet evaluated or properly modelled. The importance of exposures to carbon-14 and radon should be, if possible, included in this integrated approach.
2.3.3. **Tasks of the Working Group**

Tasks for developing an integrated approach to modelling and assessing exposure and dose to humans and biota from planned releases of radionuclides to the environment, incorporating if possible the importance of exposures to carbon-14 and radon, include but are not limited to the following.

The Working Group could focus on the following activities:

- Review and evaluate practical international and national guidance for the demonstration of compliance with requirements for the protection of the environment against ionizing radiations for planned facilities and activities,
- Review and evaluate state of the art tools, calculation tools and methods for performing dose assessments in routine radioactive discharges that can be used in integrated assessments of humans and biota, including uncertainties,
- Explore possible ways to incorporate modelling and/or identify the importance of carbon-14 and radon, and
- Identify a set of cases and scenarios where explicit assessment of the environment would be necessary. Hospital facilities and nuclear power plant facilities will be considered when identifying scenarios.

Furthermore, the Working Group could:

- Carry out dose assessments for humans and biota in identified scenarios with associated uncertainty analysis,
- Evaluate and compare models, approaches, parameters and other characteristics of the codes used in the assessments, including collaboration with the marine Working Group (7), and
- Discuss the results and give advice to the IAEA on future needs and gaps related to performing integrated dose assessments.

In addition, the tritium sub-group will investigate aspects of tritium transfer that are not yet evaluated and properly modelled. These can include:

- Influence of annual, diurnal and hourly variations of environmental conditions on the transfer of tritium in the environment,
- Model validation through comparison against results of experiments on dispersion of tritium in the environment,
- Derivation and validation of simple models for assessing short (1 day), prolonged (1-3 days) and chronic releases.

2.3.4. **Expected outcomes**

The resulting integrated approach could reduce uncertainty and improve confidence in regulatory assessments and lead to simplified approaches. This will also lead to improved guidance for biota modelling. Additional outcomes include:
— The analysis of the existing tools, codes and methodologies that can be used in the dose assessments of humans and biota,
— The evaluation of the change in the approach to explicitly assess exposure to biota and to demonstrate compliance with requirements for the protection of the environment against ionizing radiation in routine releases,
— The improvement of the models and codes by comparison with others and better understanding of the uncertainties in these assessments, including where possible, carbon-14 and radon,
— Improved modelling of exposures from tritium, and
— Improved understanding of exposures from carbon-14 and radon.

2.3.5. First meeting of the group

The first meeting of WG3 took place at IAEA Headquarters in Vienna during the First Technical Meeting of the MODARIA II Programme; 52 experts from 28 countries attended the meeting. The main objectives of the meeting were to discuss the proposal put forward by the IAEA. In addition, joint sessions with WG5 WG4 and WG7 were held.

The H-3/C-14 subgroup held independent meetings during the week, merging with the whole group in joint sessions in order to share the information on what the subgroup had achieved.

The discussion focused on the tasks based on a list preliminarily drafted by Juan Carlos Mora was held. The main point of the discussions were:

(1) National/international guidance: Not many countries include protection of biota specifically in their regulations. It was agreed that group members should follow their respective country’s legislation when carrying out assessments for this group. Alternatively they could use the DS427 approach. The group agreed that Stephanie Bush-Goddard would collect information on national legislation related to dose assessment on humans/biota.

(2) Information on codes and methods used for the calculations (eg ESTE AI, CROM8, RESRAD-BIOTA, ERICA) should be collated for the report and for this purpose it may be useful to send out a questionnaire. It was agreed that Benjamin Zorkow would prepare questionnaires to be used within WG3 on specific issues related to dose calculations and that Justin Smith would collect information about the codes.

(3) The H-3/C-14 subgroup will develop a road map this week for their proposed work plan. Nana Kwamena agreed to coordinate the work of the subgroup.

(4) Source term: A number of source terms were discussed. It was agreed that a maximum of 10 various scenarios should be used for the dose assessment, such as uranium mine (Canada), a LLW surface disposal site (France), an encapsulation plant (Finland), a hospital (India or Sweden) and a number of NPPs (eg PWR, BWR, Candu, AP1000) was agreed. It was agreed that the first source term to be used would be for the Chinon NPP, which was used in MODARIA I. It was also agreed that Juan Carlos Mora would prepare with the help of Kapil Deo Singh and Yuri Bonchuk distribute the source term(s), scenario(s), and other necessary data to the participants by December 2016.

(5) Testing the procedure: for this task dose calculations on humans and biota will be carried out. It was agreed that variable activity concentrations in the environment would be
estimated and the methodology in DS427 could be used to calculate the dose to biota. It was agreed that each participant should provide the dose assessment related to data provided under item (4) applying the methodology included in DS427 at the next interim meeting. In addition participants should provide a short explanation and the methodology for the dose calculation; to be included in the questionnaire.

(6) Analysis of results and evaluation/comparison of results (Juan Carlos Mora to co-ordinate).

(7) Final report and advice to IAEA: (Juan Carlos Mora to co-ordinate).

(8) Communication to stakeholders: An additional step was suggested which should include communication of methods adopted to protect biota to the public. (Cecile Boyer and Elisabeth Leclerc to co-ordinate).

A series of joint meetings were held with WG2, WG4, WG5 and WG7. The joint session with WG2 was held to discuss collaboration on short duration modelling of $^{41}$Ar and $^3$H. The discussion with WG4 was on how to treat the measurement results below the detection limit, the source term used by WG4 and the distributions of transfer factors. It was agreed to mutually exchange some papers for further investigations of crucial parameters used for proper dose assessments. The meeting with WG5 included an update on Volume III of SRS 19 and a presentation on RESRADBIOTA. The discussion with WG7 was about whether a scenario for the marine environment should be added. It was agreed that WG3 would provide a relevant source term to WG7 by the end of 2016.

2.4. Working Group 4 – Transfer processes and data for radiological impact assessment

2.4.1. Background

Assessing the radiological impact from radioactivity in the environment requires knowledge of a wide range of transfer processes and related data. This applies both when assessing exposures for people and for biota. It is important to understand the key transfer processes and to recognise the limitations of the way they are included in radiological assessments through parameters such as root uptake factors or $K_d$-values (to quantify the distribution of radionuclides between the liquid and solid phase in soils or sediments).

Models used to assess radiological impact can only be an approximation to reality and, therefore, comparisons between model predictions and measurement data obtained in various situations are important to improve understanding of the key processes and to explore the limitations of the models and the uncertainty in model results. The transfer processes and related data will vary depending on the situation of interest; different aspects may need to be considered for planned, existing and emergency exposure situations, respectively. There are also differences depending on the characteristics of the environment of interest.

Much of the past work in this area was relevant to temperate climates and conditions in developed countries. It is important to consider what differences there are in the assessment methodology when considering tropical, semi-tropical or arid environments. This builds on and broadens work that was carried out by Working Group 4 of MODARIA – ‘Analysis of radioecological data in IAEA Technical Reports Series publications to identify key radionuclides and associated parameter values for human and wildlife exposure assessment’. In carrying out this work it will be useful to liaise with Working Group 3 who addresses
assessments of exposure and data for planned releases to the environment, plus working group 5 who are considering assessment of exposure and effects to biota.

2.4.2. Objectives of the Working Group

— To consider the impact of the accidental release from the Fukushima Dai-ichi site in Japan in 2011 and the applicability of existing models and data to the Japanese situation.

— To identify key transfer processes for radioactivity in the environment, in the context of the situation under consideration, for use in radiological impact assessment and to provide analysis of key relevant data.

— To provide advice on the applicability of assessment models to tropical, semi-tropical and arid environments.

2.4.3. Tasks of the Working Group

The following tasks could be addressed; they can be carried out in parallel, possibly through the establishment of sub-groups.

— Consideration of environmental transfer parameters for radionuclides released from the accident at the Fukushima plant in the context of the assessment of exposures of people and the impact on biota. The key processes will be considered together with the differences between different regions of Japan and the applicability of parameters determined following the accident at the Chernobyl plant to Japan. The following sub-tasks could be addressed:

  − Compile, analyse and evaluate environmental parameters reported after the Fukushima accident including both the results of environmental monitoring and specific experiments carried out after the accident;

  − Consider the key processes of interception and retention of deposited radionuclides by plants; the transfers from soil to plants; transfer to farmed and game animals; transfers in the marine environment; losses of radionuclides through food processing and culinary preparation. Specific consideration will be given to the transfer of radionuclides to rice. In each case, identify where data are scarce and where it is possible to recommend suitable parameter values for use in Japan.

  − Consider where the situation in Japan is different from that considered in International studies and the relevance of these differences to the assessment of doses to people and the effects on biota.

— Further analyses of radioecological data in the IAEA Technical Reports Series publications. The key processes will be identified together with the important parameters that are used in the representation of these processes for radiological impact assessment involving exposures of humans and biota. The application to different exposure situations (planned, existing and emergency) will have an impact on this analysis. Where possible the data included in the IAEA Technical Reports will be analysed and expanded with advice given on the limitations of the use of the parameters generally used for assessments. In particular, the limitations and range of application of equilibrium assumptions and the use of simple biological half-lives will be considered. The following sub-tasks could be carried out:
− Methods used to model the key processes important for radiological impact assessment will be reviewed together with the way that such processes are included in assessment tools such as IAEA SRS 19.

− Following accidental releases and for routine discharges, the interception and retention of radionuclides by plants is an important factor in radiological impact assessment. It is difficult to obtain new information in this area and much of the data used to develop the parameters and parameter values for these important processes was obtained from work carried out many years ago (in the 1960s for example). This original work is not necessarily easily accessible and therefore it will be obtained, and to the extent possible, made available to the scientific community, with any gaps in knowledge identified.

− One parameter that is widely used in assessment tools is the K_d representing the transfer of radionuclides from water to soil and sediment. In MODARIA I, a critical review was carried out of K_d datasets for soil and freshwater systems. This work will be further developed to include K_d-values for marine systems and to help fill data gaps for prioritized radionuclides and scenarios as identified in MODARIA I.

− Advice will be given on the conditions for application of the K_d approach with help for users to select K_d-values and to recognise situations where it may not be appropriate to use it, as other factors (e.g. bioturbation) are important.

### Suitability of models and data for use in tropical and other environments

Much of the work to establish models and data for radiological impact assessment was carried out in temperate climates in developed countries (e.g. Western Europe and the USA) with some extension to semi-tropical regions. The models and data may not be applicable to other locations, including tropical and arid areas. The following sub-tasks will be carried out:

− Review applicability of current assessment methodologies and data for tropical and arid regions, considering factors such as possible exposure scenarios; effects of climate on growing seasons; differences in habit data; the effects of different house types on the shielding from external radiation.

− Consider the availability of transfer parameter values for tropical and arid areas, identifying where these differ from those normally provided in IAEA technical reports.

− Identify measurement datasets obtained in tropical or arid environments that could be used to test existing models, to determine their applicability to other environments.

− Identify areas where further research would be beneficial to enable improved radiological impact assessment for both humans and biota.

### Expected outcomes

− Information on environmental transfer parameters observed following the Fukushima accident, which will be disseminated to a wide audience.

− Information on the key processes for environmental transfer and the source of key information that is used widely in radiological impact assessments (such as interception factors and retention half-times on plants following direct deposition).
— A global database of Kd values for soil, freshwater and marine systems, with practical
guidance on the application of the values addressing uncertainty and the limitations of the
Kd approach.

— Information and advice on the applicability of standard models and data for the
assessment of the radiological impact in tropical, semi-tropical and arid regions.

2.4.5. First meeting of the group

Working Group 4 (WG4) held its first meeting during the First Technical Meeting of
MODARIA II; 24 experts from 14 countries attended. WG4 has three main subgroups, namely:

(1) Revision and improvement of Kd values for terrestrial, freshwater and marine systems;
(2) Collation of Fukushima data; and
(3) Radionuclide transfer parameters in non-temperate (tropical, sub-tropical and arid)
systems.

The meeting was devoted to discuss the objectives and work plan for each sub-group; identify
possible inputs by Member States and other source information; plan the first interim
meetings of all three sub-groups and finalize the report prepared under MODARIA I.

Sub-group 1. Revision and Improvement of Kd Values for Terrestrial, Freshwater and Marine
Systems

A review of the work conducted on marine Kd during MODARIA I was carried out. The
following items were agreed:

— Appropriate data should be collated to accurately derive Kd values and to investigate the
key factors that influence their variability in the marine environment.

— This data should utilise an existing database/data structure to ensure data are compiled in
the timeframe of MODARIA II

— Further information is required from the marine modelling community in order to
determine what information is required to accurately derive Kd values in marine systems.

P McGinnity (IAEA, MEL) proposed the use of the MARiS (or more detailed GLOMARD)
database for the storage of marine data, which could be modified for use in this work.

A joint discussion with members of WG7 was held to determine what factors are critical for
marine Kd values from a marine modelling perspective. Experimentally derived Kd values
should also be included as well as time dependant Kd values. This information can be found
in current literature and can be provided by Japanese WG4 members.

A tentative work plan was developed as follows:

— Contact relevant organizations to encourage provision of data for the sub-group;
— Carry out a literature review to collate relevant marine data for input into the Kd database;
— Review MARiS database structure and documentation;
— Develop appropriate database structure within MARiS to store any additional relevant
data;
— Input data into MARiS database;
— Investigate factors influencing Kd variability using data; and
— Undertake user training of updated database.

The current status of the Kd datasets for soils and freshwater was discussed. Both datasets have more than doubled in size during MODARIA I. Further inputs are anticipated for both datasets over the duration of MODARIA II.

A significant amount of time was used to revise and improve the draft MODARIA I report. A greatly improved version was prepared and distributed with a deadline of end November 2016 for revised text with response to queries.

A joint meeting was held with members of WG3 in order to discuss various aspects of the report, after which the draft report was sent to WG3 and it was agreed to include some additional information on distribution of the data for some animal parameter values. The possibility of harmonizing terrestrial, freshwater and marine datasets should be explored.

Sub-group 2. Fukushima Parameter Datasets

The aims of this sub-group are to:

— Collate datasets on selected transfer parameters or processes in Japan;
— Provide environmental transfer parameters obtained after the Fukushima accident; and
— Compare the collated parameter values with those in TRS 472 and reported after previous events (e.g. Chernobyl accident and global fallout).

The group agreed to initially compile datasets for the following ecosystems:

— Forest (radiocaesium concentration change in tree leaves, branches, bark, understory plants, throughfall, litter, soil, and vertical migration in soil);
— River (radiocaesium concentration change in river water soluble and SS fractions, and sediment);
— Marine biota (radiocesium concentration change in biota [tissues], water-biota concentration ratio);
— Freshwater biota (same as marine biota [tissues]);
— Rice (TFs, inflow and outflow in paddy field);
— Agricultural crops (TFs);
— Game animals (Tag); and
— Food processing (radiocesium removal rates).

The data compilation will include consideration of journal papers (both English and Japanese) and grey literature (open data sources and institution reports in Japanese).

Japanese research group leaders will make the specified datasets under consultation and discussion with international associate experts, currently identified from the IAEA, UK, France, Spain, USA, Australia, Korea and Germany.
Sub-group 3: Transfer Parameters in Non-Temperate Systems

The objectives of the sub-group are:

1. To collect and review available data on radionuclide transfer to plant and animal products in non-temperate (tropical, sub-tropical and arid) systems.

2. To compare transfer parameters for non-temperate and systems with those of TRS 472/TECDOC-1616 for temperate areas.

The sub-group will interact with an established IUR Task Force collating available information in arid areas in Europe, Asia and Africa and the Americas. The data from Japan are probably more relevant for temperate areas and will not be included. WG4 has access to the relevant datasets and the format of the WG4 dataset will be reconsidered to ensure that it is suitable for these climate areas. The sub-group will revisit the FAO/IAEA report on transfer factors coordinated by Martin Frissel, explore the IUR transfer databank by N. Mitchell and collate newly published or available information from other sources. It will explore cooperation with relevant regional IAEA TC programmes and CRP projects to identify additional data. Further efforts will be made to access information for nuclear test sites in China, the USA, Australia, Polynesia and Kazakhstan. WG4 participants from India and Egypt are ready to provide measurement data on terrestrial transfer from national projects. India will provide the relevant data, pertaining to the country, published in open literature. In addition, Che Doering will share data with the group, while Megan Cook, as coordinator of the regional ALMERA group in Asia offered to approach her counterparts for additional measured data in tropical/subtropical environments.

2.4.6. Work performed in 2017

Meeting of WG4 Subgroup 3 on Transfer Parameters in Non-Temperate Systems

The 2017 Interim Meeting of WG4-SG3 was held at the Institute of Nuclear and Radiological Sciences and Technology, Energy Safety (INRASTES) National Center for Scientific Research “DEMOKRITOS”, Athens, Greece from 6 to 7 April 2017. Unfortunately, some participants were unable to attend or had to cancel their participation in the last minute. The main objective of the meeting was to discuss interim results and how to proceed further.

Ms Natalia Semioshkina and Ms Gabi Voigt presented some Excel spreadsheet templates, and the group discussed in detail the structure of the data bank. To date, over 200 publications in 23 countries with arid climates have been collated so far. Ms Konstantina Kehagia presented the results of U-238/U-234 and Ra measurements in seawater, surface river water and freshwater from her monitoring studies. Ms Florou presented her latest results on concentration ratios in natural biota and her comparisons of natural reference organisms with model comparisons using the ERICA tool.

Members of this subgroup will continue to provide published or unpublished data from their networks and connections, (e.g. Mr Pérez-Sánchez will provide radioecological data from Niger collected by AREVA; and Mr Eleftheriadis will set up a contact to corresponding organisations in Algeria, Morocco and Tunis).

The subgroup agreed that the data evaluation should reflect the recommended TECDOC-1616 classification so that values can be directly compared: no laboratory experiments but only field experiments under normal agricultural conditions (i.e. fertilizing, irrigation) should be considered; conversion factors dry to wet should be included; data should be categorized according to 4 soil type classes and 8 vegetation classes.
For the quality assurance and control, the subgroup agreed on a 4 factors that can be used to determine the quality of the data: (1) intercomparison studies conducted, (e.g. ALMERA); (2) sampling strategy and protocols (systematic sampling) available; (3) data evaluation and statistics provided; and (4) equipment and metrology clearly described.

All data will be analysed accordingly in order to deduce transfer parameters and will in turn be made available for the IAEA database. Transfer to fruit and to other products (e.g. plants and animals) will be treated separately in the IUR taskforce data bank taking into account the TECDOC-1616 considerations. The transfer factors (TFs) obtained can be directly used for comparison studies as presented by Mr Sergey Fesenko, who demonstrated first results with significantly higher TFs for Cs-137/Sr-90 in tropical environments, compared to tendentially lower TFs in subtropical environments.

Meeting of WG4 Subgroup 1 on Revision and Improvement of Kd values for Terrestrial, Freshwater and Marine Systems

The 2017 Interim Meeting of WG4-SG1 held at the IAEA Environment Laboratories in Monaco from 31 May to 2 June 2017. Nine experts from 7 countries attended; in addition a number of staff members from IEAE MEL also participated. The main objectives of the meeting were to investigate the options for the development of a global database of Kd values of the marine environment, and to investigate the options for the harmonization of datasets for terrestrial, freshwater and marine systems.

Mr Paul Morris gave an overview of the MARiS database and a discussion was held on the potential of using the MARiS database for the generation and the storage of Kd values and other relevant factors (i.e. metadata) influencing Kd variability. There are plans to update and review the database in the next few years, to include more data and seeking feedback from users on how it can be improved. It was clear from the discussions that MARiS has the potential to generate Kd values and so work will be carried out to review the relevant data in MARiS with a view to generating Kd values from the database. Mr Kevin Kelleher agreed to provide metadata requirements to Mr Morris for marine Kd values and to conduct some preliminary investigations into MARiS prior to the next meeting (see below).

Mr Kelleher presented a proposal for the development of a global marine Kd database to the participants of the meeting. This draft project plan did not contain any proposals for inclusion of the Kd values from terrestrial or freshwater systems and it was agreed that it was important to include this data in any future development of a Kd database. Mr Miquel Vidal and Mr Patrick Boyer gave an overview on the developments of the soil and freshwater Kd value datasets. The need to develop a similar dataset for marine Kd values was identified before a global unified database for Kd values could be proposed. Therefore, the work of the WG4-SG1 should focus on the development of the marine Kd dataset and the development of a proposal for a unified global database for Kd values in the terrestrial, freshwater and marine systems. The IAEA have agreed that there is a requirement for such a database and it needs to be sustainable. Therefore, Mr Kelleher agreed to investigate the possibility of the IAEA hosting this Kd database into the future.

The commonalities between soil, freshwater and marine Kd datasets were discussed with a view to investigating the possibility of organizing the three datasets into the same database structure. It was felt that there was a need to move towards a common language across the datasets and there were obvious similarities between the marine and freshwater systems, with some similarities existing between the marine sediment and soil systems. The starting point
for this work will be to look at the data submission form for the freshwater dataset and see if it can be utilized for the other systems.

A joint meeting between the members of WG4-SG1 and WG7 was also held in order to obtain feedback from the marine modelling community on their requirements on the use and application of Kd values in the modelling of dynamic situations. WG7 also demonstrated the use of Kd values in two separate marine models that were being compared. Kd values were not used directly in these models but they were used to derive exchange velocities. It was stated that the influence of Kd values did not have a significant influence on the overall outputs. These models were also used to derive the apparent Kd values as a result of the contamination and it was demonstrated that after 90 days the Kd values still had not reached an equilibrium value. It was suggested that these results be compared to real world data. Further collaboration will take place with WG7 utilizing experimental Kd values in marine models.

2.5. Working Group 5: Exposure and effects to biota

2.5.1. Background

The revised BSS require the consideration of the radiological impact on the environment when planning and applying for an authorization for new nuclear facilities. During the last years, many efforts have been devoted to develop models allowing biota dose assessment as part of the regulatory process of licensing and compliance monitoring of authorized releases of radionuclides. Even if the assessments performed until now have not indicated any particular risk of effects on biota at the population relevant level under planned exposure situations, there is an increased interest from society on environmental issues, resulting in the need for an explicit demonstration of the protection of the environment, which will lead to building and reinforcing public confidence.

In existing exposure situations (post-accidental situations, legacy sites), biota dose assessment could also be useful for the purpose of public information and transparency. At the same time, the optimization of the protection of humans in existing situations should take into account not only the reduction of doses to the public, but also economical, societal and environmental implications. To achieve these aims, efforts in both the simplification and improvement of models are necessary, which are currently used for estimation of doses and the associated uncertainties. In addition, when assessing radiation exposure for both humans and wildlife, common pathways and processes can be identified, mitigating for an integration of modelling exposure for both humans and biota. The development of a human-biota integrated assessment model will be under the responsibility of WG3; nevertheless, inputs from WG4 are expected.

The aim of radiological protection of biota is related to higher organizational levels of populations of species and communities of different species rather than for the limitation of individual risks as is the case for humans. The estimation of possible consequences to populations is an important step in exploring the ecological relevance of dose estimates for flora and fauna.

2.5.2. Objectives of the Working Group

Currently, several assessment approaches and associated tools exist, as e.g. the RESRAD-biota-tool, the ERICA tool, and the approach developed by the ICRP. Based on these existing
models, the main objective of the working group will be to test, validate and perform intercomparisons and to improve these different approaches/models, with specific consideration to the demonstration of protection at the population level. This work will include both the transfer to biota models and the dosimetric approaches used. Specific attention will be paid to the consistency of the models applied to fulfil regulatory requirements.

The ultimate goal of radiological protection of biota is to avoid harmful effects to populations of living organisms. At the present time, it is acknowledged that models for predicting effects of radiation at the population level are far off being operational for practical assessment. Taking advantage of the work performed in this domain during the EMRAS/MODARIA programs, the objective of the WG will be to apply and test existing population models with regard to data for different exposure situations.

2.5.3. Tasks of the Working Group:

The working group could address the following tasks:

— Validation test, comparison and improvement of conceptual and mathematical models for biota dose assessment:
  
  – As different approaches and models (such as RESRAD, ERICA Tool, ICRP approach) are available, the WG could test and compare them with the objective of evaluating if they are fit for purpose and to test the underlying assumptions.
  
  – As datasets are starting to appear from post-Fukushima studies in Japan, these could be used – among others – for model testing and evaluation.
  
  – Model testing and improvement will in particular focus on dosimetric approaches, on spatial dimensions (interaction of spatial distributions of populations and spatial distribution of radionuclide activities per unit area) and on dynamic modelling.

— Testing and validating population models:
  
  – Based on the work performed during the EMRAS and MODARIA programmes, the main task will be to test and compare the previously identified population models. This includes testing them against laboratory and field data, if available.
  
  – Linking to the doses in real situations where there may be a need to regulate, from routine to accident situations, testing whether there are effects at agreed benchmark levels. Determining what is the critical proportion of a population that needs to be affected to cause long-term population effects.

2.5.4. Expected Outcomes:

— Evaluation of uncertainties (and ways of reducing them if any) associated with the different approaches and models.

— Development of simplified approaches for biota dose assessment (“graded approaches”).

— Availability of tested and improved models to estimate possible effects to populations and indication for the necessity of such assessments with regard to regulatory requirements.

— Guidance reports and training materials on the use of models that allow assessments to biota and of models that allow integrated assessments of doses to humans and biota.
2.5.5. First meeting of the group

The first meeting of Working Group 5 was held during the First MODARIA II Technical Meeting. Thirty experts from 14 Member States attended the meeting. The objectives of the Working Group were presented by Nick Beresford and Jordi Vives during the opening plenary session. In relation to radiation effects Jordi explained that there would probably be four ‘research lines’ and the work of the group would focus on the regulatory aspect for which the efforts of modellers, radiobiologists, ecologists and regulators would be combined. He added that information needs to be gathered to feed gaps in the effects for some doses within the benchmark bands and asked people to share relevant data with the group.

Sub group on Effects (lead: Jordi Vives i Batlle)

The main meeting for the radiation effects-related topic took place on Tuesday, 1 November 2016 and had the following structure:

(1) Presentations by participants – setting the scene:

(2) Discussion “what questions does the IAEA expect the group to answer” – the group agreed that WG5 should try to address a number of specific questions which can be used as the basis for the structure of the group report:

1. What is the dose rate at which we can start seeing effects at the ecosystem level? The group will provide guidance to help understand where benchmark bands sit in terms of an emergency and how population models can be used to produce guidance to this end, with the possibility to explore what the consequences are on populations.

2. What percentage of the population needs to be affected in order for the effect to affect the whole population? A number of topics will be discussed, such as signalling, bystander effect, spatial issues and the ‘critical’ size that needs to be affected to cause long term population effects. This links to applying population models in the field. We highlight this as a collaboration – integrating activity – between the two sub-groups of WG5.

3. How robust are the existing benchmarks for exposure to biota populations? This encompasses issues like earlier exposures, population emigration, what data is appropriate to use, interactions between populations of different species, and how we interpret them. We should try to provide the IAEA with evidence to defend these benchmarks and with arguments to defend them when they are challenged – we know there are such challenges made to the regulators made by stakeholders.

The group agreed that population models would be used as a tool to answer the questions, but should not be used as part of regulatory assessments. We also emphasise that we are aware of new data becoming available and as they do, we will consider them.

(3) Initial projects to start (what, link to regulation, who?) – the group went through a series of possible initial activities agreeing which could be started immediately, and those which are subject to feasibility study and will be decided upon during the next (mid-term) meeting;

(4) Discussion on the report of MODARIA I WG9 on Effects – a core group of experts was created to finish the report.

Sub group on Exposure modelling (lead: Nick Beresford)
Discussions were focussed on the presentation of suggested activities, ad decisions on what to take forward and also on-going activities from MODARIA I. The aims of this activity of WG5 are to:

- Demonstrate fit for purpose regulatory models;
- Validate, test, improve models for different applications;
- Provide good practice guidance.

Joint meetings were held with WG1 and WG5. As far as the interaction with WG1 it was agreed that a sub-group from WG5 would undertake biota dose assessment modelling for WG1 scenarios. It was also agreed that a joint session would be held during mid-term meetings. As far as the interaction with WG3 the group felt that the suggested activities within WG3 were potentially repeating earlier work of the EMRAS/MODARIA I ‘biota modelling’ WGs and that there was potential overlap (and hence a collaboration opportunity) within the MODARIA II programme. It was therefore suggested that the relevant output from the EMRAS/MODARIA I ‘biota modelling’ WG should be supplied to WG3 so that they could avoid repetition and learn from the previous activities. However no agreement on collaboration between the 2 groups was reached.

Key discussion points and actions arising are presented below:

- Lessons learned paper – the plan is to complete this paper started within MODARIA I by the mid-term meeting as it may be a useful input to WG3. Some guidance on how to measure whole-body activity concentrations in wildlife will be included in the paper.
- Animal-Environment interaction modelling:
  - The aim is to complete the moose work which started in MODARIA I by the mid-term meeting;
  - The WG agreed to take forward the reindeer study which was discussed during MODARIA I as a modelling exercise within MODARIA II. A 12 month field study (by the University of Salford, NERC-CEH and NRPA) will provide external dose rate measurements and internal activity concentrations for the reindeer
  - Karine Beaugelin-Seiller agreed to see if it is possible to get data from an IRSN study of wolves in Chernobyl.
- Transfer modelling:
  - Building on work started within MODARIA I, we plan to begin analysing the wildlife CR database (the ‘WTD’) in greater detail. The MODARIA I work comparing CRs at the organism group level suggested that, for screening purposes, simply having a vertebrate CR and an invertebrate CR may be best;
  - Arctic data will be compared with other data in the WTD, while the possibility of separating out data for other climatic zones (e.g. tropical) will be investigated and the appropriateness of vertebrate/invertebrate screening CRs will be assessed further;
  - Japanese freshwater data provided by M Tagami will be used to calculate CRs. The data also presents an opportunity to study variability in transfer between years in the post-accident period and compare these transfer data with data from other geographic regions (the dataset also contains useful life stage data). The dataset will
also be used to test new taxonomic (or REML) models which are becoming available. The REML model will also be tested against other geographic areas, e.g. Australia.

- The database on biological half-lives published within MODARIA I will be analysed to see whether new allometric relationships can be established and uncertainty in modelling reduced. Consideration will also be given to whether it is possible to account for age.

— IAEA Safety Report Series approach for ‘wildlife’: the WG plans to compare the wildlife component of the approach included in the updated SRS 19 report, which is expected to be published during MODARIA II, with other non-human biota approaches using scenarios.

2.6. Working Group 6 — Biosphere modelling for long-term safety assessments of high level waste disposal facilities

2.6.1. Background

Within the framework of performance assessments of radioactive waste disposal facilities, the demonstration of long-term safety and the compliance with dose criteria for hypothetical members of the public are key issues. Long-term dose assessments are partially built upon a sound scientific basis, addressing climate change, the development of landscapes and transport processes of radionuclides within the biosphere. They are complemented with a set of plausible assumptions, e.g. with regard to the technological status of future communities and human living habits.

The MODARIA I Working Group “Common framework for addressing environmental change in long term safety assessments of radioactive waste disposal facilities” developed a methodology to evaluate the consequences of climate change and landscape development, including the identification of CO₂ emission scenarios and an approach to relate the long-term CO₂ concentrations in air to the evolution of many environmental variables on a kilometre scale. The methodology is considered to be applicable to a wide range of facilities and site conditions and was suggested to be incorporated in an update of the BIOMASS-6 methodology.

2.6.2. Objectives of the Working Group

The objective of Working Group 6 is to critically review the conceptual basis for long-term dose assessments and, more specifically, the benefits and limitations of the conceptual framework for addressing environmental change in long term safety assessments developed in MODARIA I. This objective includes an update and extension of the BIOMASS-6 methodology. The focus will be on the practical application, including approaches to quantitatively estimate the long-term exposure of hypothetical members of the public and populations of non-human biota, to provide guidance on how to use site-specific information and available data, and general recommendations on how to estimate the uncertainty budget and communicate the assessment results.

This could be addressed by:
— Analysing existing concepts for long-term dose assessments, addressing e.g. climate change and landscape development, with regard to their scientific basis and complementary plausible assumptions.

— Critically reviewing the benefits and limitations of the conceptual framework for addressing climate change and landscape evolution in biosphere modelling in MODARIA I, identifying conceptual and/or information gaps and further developing it with regard to completeness, consistency and applicability.

— Providing guidance on site characterization (type of information, level of detail) and the data required for the long-term assessment of radioactive waste disposal facilities, including recommendations on how to use information and data in the most efficient way.

— Extending and refining the BIOMASS-6 methodology, focusing on practical applications and quantitative predictions of the long-term exposure of hypothetical members of public.

2.6.3. Tasks of the Working Group

The work could be divided into the following tasks. Initial tasks can be executed in parallel:

— Review of the conceptual framework for biosphere modelling, taking into account
  — the framework for addressing environmental change developed in MODARIA I,
  — the modelling considerations and results concerning environmental change achieved in IAEA EMRAS II WG3,
  — the results of the IAEA HIDRA project on effects of human disturbance,
  — the experience gained through example applications of the BIOMASS-6 methodology, other relevant assessments, and site characterisation and research activities since the publication of BIOMASS-6 methodology in 2003.

— Analysis of long-term dose assessments with regard to their scientific basis and complementary plausible assumptions and description of the consequences for estimating the uncertainty budget and communicating the assessment results.

— Identification of conceptual and/or information gaps, including, as already identified, further consideration of climate change and landscape development in the first few hundred to 1000 years after disposal operations cease.

— Further development of the framework aiming at completeness, consistency and applicability, including assessment framework for demonstrating environmental protection.

— For selected real or hypothetical waste disposal sites:
  — Analysis of the importance of initial site characteristics and identification of information/data needed for the long-term assessment of these sites.
  — Demonstration of how to use this information in the most efficient way.

— Update and extension of the BIOMASS-6 methodology, including the development of “Biosphere Dose Conversion Factors” (or equivalent simple mathematical models) for a set of reference cases, inland sites, coastal sites and sites representing a range of different ecosystems.
The completion of these tasks will be substantially supported through analysis of results of the already mentioned IAEA projects, a variety of EU projects such as BIOCLIM and BIOMOSA. The tasks will also be supported by the substantial output of collaborative activities in the BIOPROTA Forum for addressing key issues in biosphere aspects of assessment of the long-term impact of contaminant releases associated with radioactive waste management. In particular, this will include the results of the on-going project on Review and Enhancement of the BIOMASS-6 Reference Biospheres Methodology, due to complete in 2017. This project in turn relies on the results and experience gained since 2003 at the national level from many countries.

2.6.4. Expected Outcome

The expected outcome could be:

— A handbook describing a systematic, transparent and robust conceptual framework for site specific and site generic biosphere assessments for radioactive waste disposal facilities. The stepwise approach will account for long-term climate change such as modifications of sea level; it will be flexible to enable adaptation to the system under assessment and the specific regulatory requirements.

— A report on the scientific basis of existing long-term dose assessments and complementary plausible assumptions. This report will also address the consequences of this hybrid approach, including general guidance on how to estimate the uncertainty budget and to communicate the results of long-term assessments.

— An updated and extended version of the BIOMASS-6 methodology, including easily applicable numerical values/mathematical models to assess the long-term dose to hypothetical members of the public and information to support the demonstration of environmental protection in assessments.

The results of Working Group 6 are relevant to all countries developing and operating disposal facilities for radioactive waste. The results will also be relevant to countries with closed disposal facilities that are still under regulatory control. The link to long-term legacy site management is also noted.

2.6.5. First meeting of the group

The first meeting of Working Group 6 was held during the First MODARIA II Technical Meeting. A total of 29 participants representing 14 Member States attended. In addition, interest to participate in the WG was expressed by a number of organisations, whose representatives were not able to attend this initial meeting. The objectives and scope of the group were agreed in line with the IAEA July 2016 WG6 proposal, with allowance for flexibility as the work progresses. It was agreed to structure WG6 activities around the main steps in the BIOMASS Methodology, with particular areas for enhancement in brackets:

— Assessment context;

— Biosphere system identification and justification (climate development and downscaling);

— Biosphere system description (discharge areas, near surface investigation methods, landscape development, with emphasis on first 1000 y, human actions, wildlife behaviour and protection of the environment);
— Potentially exposed groups (principles for defining representative humans, populations of wildlife);

— Model development (biosphere and supporting model definition, conceptual and mathematical models and data provision – actions follow from system description activities);

— Calculation;

— Iteration (confidence building and communication).

It was noted that the range of environments and assessment topics of interest in WG6 encompasses much of the scope of other MODARIA II WGs, but special interest and overlap was noted with WG1, in connection with assessments for sites which present both contamination land and waste disposal facilities.

2.6.6. Work performed in 2017

The 2017 Interim Meeting of Working Group 6 (WG6) was held 10–12 May 2017, hosted by the Swiss Federal Nuclear Safety Inspectorate (ENSI), in Brugg, Switzerland. This interim meeting was held in conjunction with a workshop of the BIOPROTA Forum on review and enhancement of the IAEA BIOMASS Methodology. A total of 28 registered WG6 participants representing organizations from 10 IAEA Member States attended. In addition, the meeting included participants from Public Health England, Clemson University (USA) and Facilia AB (Sweden). Mr Russell Walke presented progress on the update and extension of the BIOMASS methodology to-date, including the output provided by the BIOPROTA project which has similar objectives to WG6. The objectives of the meeting were to provide a forum to draw on experience; discuss a broad range of issues relating to biosphere assessment, structured around BIOMASS methodology; begin to refine plans for reporting and assign ownership and actions.

It was reiterated that the intention is to retain the same basic steps as the BIOMASS Methodology but to provide further clarification where this appears useful, introduce adaptations where new issues have been identified, and provide further illustrations based on a wide range of experience gained since 2001. It was noted that the BIOPROTA Project is due to complete at the end of 2017, whereas the overall MODARIA II Programme, including WG6, is planned to go forward until 2019. The main results of the meeting were:

— It was agreed to structure continuing WG6 activities around the main steps in the BIOMASS Methodology;

— A number of subtopics and issues, were also being considered to be input to an interim report (see paragraph below) and/or be discussed during the next WG6 meeting;

— It was also noted that the use of “Intelligent Kds”, a supporting model initiative for Kd determination, can be discussed during the next meeting;

— It was agreed that it would be extremely valuable to produce an interim report at the end of 2017 on the review and enhancement of the BIOMASS Methodology. This will be issued as a report prepared under the BIOPROTA Forum, but in this case, with the cooperation of the IAEA. The report will document progress at the time of publication, reiterating the continuing relevance of the main features of the Methodology, illustrating its use (largely by reference rather than by duplicating published examples), presenting enhancements, illustrating them (again by reference, as far as possible), and identifying remaining areas for clarification. These points will be examined further within the
continuing MODARIA II WG6 programme of work. A draft report will be compiled from the various inputs by the BIOPROTA BIOMASS Project Technical Support Team and presented during the next WG6 meeting.

— It was noted that the range of environments and assessment topics of interest in WG6 encompasses aspects of the scope of other MODARIA II WGs. Special interest and possible overlap remains with WG1 (and WG1 of MODARIA I) in connection with assessments made to support decisions for sites which include both contaminated land and waste disposal facilities. Special interest was also noted in connection with assessment of exposure of relevant populations of non-human biota, in progress within MODARIA II WG4.

2.7. Working Group 7: Assessment of fate and transport of radionuclides released in the marine environment

2.7.1. Background

The Fukushima Daiichi accident, which caused significant releases to the marine environment, prompted a large interest in the modelling of transport and transfer of radionuclides in marine systems. In the frame of the MODARIA I programme, two scenarios have been studied: Chernobyl deposition on the Baltic Sea and dispersion of Fukushima releases in the Pacific Ocean. A very good agreement in model-model and model-data has been obtained for the Baltic Sea exercise, whereas blind models-model inter-comparisons for the Fukushima case have resulted in significant differences between them. It has been shown that the main reason for these differences was an extreme sensitivity to the water circulation in environments characterized by rapidly changing currents. These results raise questions about the use of marine dispersion models when used to support decision making after an accident in the marine environment.

During the last years, many efforts were devoted to emergency situation studies; however, modelling fate and transport of radionuclides in marine environment is also of interest for environmental impact assessment in connection with controlled discharges from various sources as e.g. by the nuclear industry, and the oil and gas industry.

2.7.2. Objectives of the Working Group

— To assess sensitivity and uncertainties in model predictions (in particular in connection with water circulation knowledge) and the relevance of their use to support decision making in emergency situations.

— To improve models describing the fate of radionuclides in marine environments through the addition of processes not yet implemented.

2.7.3. Tasks of the Working Group

— To explore the limitations on the use of dispersion models in marine environments, when used to support decision making in emergency situations: For this question, several points will be considered based on scenarios to be defined and on existing and available data sets (e.g. the Fukushima situation):
  − Assessment of the main sources of uncertainties related to the use of the different models tested;
— Sensitivity analysis focusing on water circulation parameters knowledge;
— Recommendations on the ability and limitations of the tested models, for the situations in which they are used to support decision making.

— Improvement of models describing the fate and transport of radionuclides in marine environments. So far, models tested take into account the dissolved phase and predict (through simple water-sediment interaction parameters) the contamination of sediments. The working group will work on the improvement of models addressing:
  — Improvement of the description of water/sediment interactions (interaction with WG 4 expected);
  — Improvement of the description of physico-chemical processes occurring in sediments and
  — Integration of a dynamic biota model that allows predicting the contamination of food sea products.

— Modelling of transport and fate of radionuclides in marine environments, with the aim of environmental impact assessment; dispersion models can also be used in the framework of environmental impact assessment related to radionuclide discharge in seas. Off-shore oil and gas industries are a source of discharges of natural radionuclides to the marine environment. The ability of dispersion models to predict the long term fate of these discharges will be tested through model-model and model-data (if available) comparisons.

2.7.4. Expected outcomes

— Guidance on the limitations of the models to predict radionuclide dispersion in emergency situations.
— Guidance on the reliability of models for predicting dispersion under different situations (short term or long term).
— Improvement of fate and transport models by addition, in a manageable way, of processes not yet implemented.

2.7.5. First meeting of the group

The first meeting of Working Group 7 was held during the First MODARIA II Technical Meeting. Fourteen experts from 14 Member States attended the meeting. On the first day of the meeting a number of presentations related to marine modelling of radionuclide dispersion was given by the participants. After that, discussions on the modelling scenarios to be studied in order to achieve the WG’s objectives took place. Three tasks were proposed:

(1) North-Atlantic Scenario – Long term simulation of historical releases from La Hague and Sellafield. It was agreed that a detailed description of the scenario, together with input data would be prepared by USEV (Raúl Periáñez) and distributed by the beginning of 2017.

(2) Pacific Scenario – It consists of long term simulations of Fukushima releases in the same way as for the North-Atlantic. It was agreed that a detailed description of the scenario, together with input data would be prepared by JAEA and KAERI and distributed to all participants by the beginning of 2017.
In addition, a joint meeting was held with WG3 who have agreed to provide source terms for several radionuclides describing the potential releases from a nuclear facility into the sea. WG7 will calculate concentrations of radionuclides in water and sediments, averaged over a square around \(10 \times 10\) km\(^2\). A joint meeting was also held with WG4 in order to address difficulties in the determination of K\(\text{ds}\) in the marine environment and their use in marine models. A document describing the problematic of measuring K\(\text{ds}\) in the marine environment near a release point of radionuclides was prepared and provided to the WG4 Leader (Brenda Howard). It was clearly stated that ratios between activity concentrations in sediment and water close to a radionuclide release point are not real K\(\text{ds}\) and should not be included in K\(\text{d}\) databases.

2.7.6. **Work performed in 2017**

The 2017 Interim Meeting of WG7 was held at the IAEA office in Monaco from 31 May to 2 June 2017; 11 experts from 8 Member States attended. The main objective of the meeting was to discuss the three modelling exercises were defined during the first MODARIA II Technical Meeting, in particular input data and model outputs were discussed. Contrary to the scenarios studied during MODARIA (Phase I), the area covered by WG7’s work is to be extended to include long temporal and large spatial scales. Moreover, models will also include a biological uptake model (BUM), integrated within the dispersion model.

1. **North-Atlantic Scenario** – Historical releases of \(^{137}\text{Cs}\) from Sellafield and La Hague (1952–2006) have been compiled, as well as water velocity fields in the form of monthly averaged current fields. Some preliminary simulations have been carried out and these results were presented during the meeting and discussed by the group.

2. **Pacific Scenario** – Fukushima \(^{137}\text{Cs}\) direct releases to the ocean from March 2011 to December 2011 have been reconstructed, as well as \(^{137}\text{Cs}\) deposition on the sea surface. Deposition fields have been constructed from two atmospheric dispersion models and provided as daily integrated values. Monthly averaged water current fields have also been compiled and provided and some preliminary simulations have been carried out. These results were presented during the meeting and discussed by the group.

3. **1D sediment exercise** – Basic sediment properties plus K\(\text{d}\) and kinetic rates have been provided. Moreover, bottom currents and \(^{137}\text{Cs}\) concentrations in bottom water have been compiled from previous results obtained during MODARIA (Phase I). Different models to simulate the contamination of the sediment will be applied, using the provided bottom currents and caesium concentrations as boundary conditions. Some preliminary simulations have been discussed.

A joint meeting with the MODARIA II Working Group 4 K\(\text{d}\) Subgroup was held. Basic requirements in marine dispersion models, in order to simulate water/sediment interactions, were described by members of WG7. Practical questions posed by WG4 in relation to a K\(\text{d}\) database potential characteristics were answered by WG7 members.