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Test-run of course modules

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STAR
STRATEGY FOR ALLIED RADIOECOLOGY

EURATOM

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Executive Summary

A sustainable nuclear energy programme requires a trained and competent workforce. To achieve this vibrant and sustainable skill base in radioecology and a long-term training and education within the nuclear sciences is required.

Within radioecology it is essential to focus on both the recruitment of future employees as well as securing the competence of the present workforce. The ultimate goal of STAR's educational and training (E&T) components (WP-6) is to set up a set of courses for both worker training and student education in an integrated and sustainable way.

This deliverable provides information on the implementation and test runs of course modules within radioecology, describing the content of the courses, experts teaching the courses, number of students and trainees participating, as well as the development of the courses held within STAR.

A total of four courses were planned within STAR WP6 (one MSc. course, on PhD. course and two professional development training courses) to help meet some of the needs within radioecology. The restructuring and development of the courses has benefited from the input of the both the STAR participants and the STAR E&T stakeholders (see Deliverable 6.1). In addition to these planned courses, other courses have been held including web-based courses on Biological Ligand Model (BLM) and mixture toxicity. A new course module in modelling has also been prepared.

The courses aim, not only to fill the identified European postgraduate education gap in radiological sciences, but also to provide a modular structure that is easily accessed by stakeholders for professional development training. It was anticipated that the European Masters course would provide the academic training such that students can be considered "qualified experts", as defined by the European Commission and the IAEA.

The following intensive modules have been or will be provided by the STAR consortium:

- MSc Experimental Radioecology/Radioecology
- PhD Environmental Radiobiology
- STAR Mixture Toxicity, Dynamic-Energy-Budget (DEB) and risk assessment – a training workshop
- Radiological Protection of the Environment - a professional development training course

The courses attracted students from different countries and included PhD students, MSc students and the evaluation and feedback by the participants was overall good.

Table of Content

1. Introduction

A sustainable nuclear energy programme requires a trained and competent workforce. To achieve this vibrant and sustainable skill base in radioecology and a long-term training and education within the nuclear sciences is required. Within radioecology it is essential to focus on both the recruitment of future employees as well as securing the competence of the present workforce. **The ultimate goal of STAR's educational and training (E&T) components (WP-6) is to set up a set of courses for both worker training and student education in an integrated and sustainable way.**

Such needs are particularly acute in a field where formal training and education is fragmented, often inadequate, and where mobility is an essential means to support competence sharing.

The overarching objectives of WP-6 are to: 1) strengthen and secure a sustainable integrated European training and education platform in radioecology that will attract top-level graduates, 2) maintain a workforce that is in a position to meet future economic and societal needs within the nuclear sciences, and 3) enhance the mobility of teachers and STAR scientists as a means to secure a goal of competence building.

To meet the objectives STAR will:

- consult and engage with stakeholders on the present status and the training and education needs within radioecology as an essential part of nuclear sciences (month 12),
- consolidate a sustainable, integrated, training and education platform in radioecology directed to research scientists, stakeholders and students; explore mechanisms to stimulate student interest in training and education (month 30),
- implement and test a selection of syllabus revised modules within radioecology, utilizing the mobility of expert teachers and as well as of students and trainees (month 36),
- secure funding mechanisms for scientists and student mobility and long-term sustainability of the training and education platform in radioecology (month 48).

This deliverable provides information on the implementation and test runs of course modules within radioecology, describing the content of the courses, experts teaching the courses, number of students and trainees participating, as well as the development of the courses held within STAR.

2. Background

In 2000, the OECD/Nuclear Energy Agency's report: "Nuclear Education and Training: Cause for Concern?" demonstrated that many nations were probably training too few scientists to meet the needs of their current and future nuclear industries. Additional studies undertaken by different European projects (EURAC, ENEN-II, FUTURAE) and international organisations (IUR) confirmed the OECD/NEA findings; decreasing student interest, decreasing course numbers, ageing faculty members and ageing facilities. Consequently, the European educational skill base has become fragmented to a point where universities in most

countries lacked sufficient staff and equipment to provide education in all, but a few, nuclear areas. Of particular concern to the stakeholders (EU Commission, authorities, industry and professionals) are the significant and persistent needs for post-graduates with skills in radiochemistry, radioecology including environmental modelling, and radiation protection including radiobiology and dosimetry.

The course modules presented are included in the STAR education platform that offers training and education possibility within radioecology/environmental radioactivity, and will also provide links to education platforms within other fields of nuclear sciences.

3. Timing and Realisation of the STAR Course modules

3.1. STAR courses planned

A total of four courses were planned within STAR WP6 (one MSc. course, on PhD. course and two professional development training courses) to help meet some of the needs within radioecology. The restructuring and development of the courses has benefited from the input of the both the STAR participants and the STAR E&T stakeholders (see Deliverable 6.1). In addition to these planned courses, other courses have been held including web-based courses on Biological Ligand Model (BLM) and mixture toxicity. A new course module in modelling has also been prepared.

The courses aim, not only to fill the identified European postgraduate education gap in radiological sciences, but also to provide a modular structure that is easily accessed by stakeholders for professional development training. It was anticipated that the European Masters course would provide the academic training such that students can be considered "qualified experts", as defined by the European Commission and the IAEA.

3.2. STAR Course modules provided

The following course modules have been provided by the STAR consortium as PhD, MSc and training courses:

- Experimental Radioecology/Radioecology: The students gained knowledge about radioecology (i.e. source terms, ecosystem transfer and behaviour of radionuclides in the environment), as well as biological effects, impact and risk assessment based on radiochemistry and radiation protection. Case studies include NORM, accidental situations, the nuclear industry and waste management.
- Environmental Radiobiology: The students gained knowledge on the fundamental principles of radiobiology, but within the context of effects on non-human biota. The course covered both the history and the state-of-the-art of our knowledge on the biological effects of radiation on humans, including how recent studies are challenging established paradigms, but concentrated specifically on those issues and applications of most relevance for other organisms

- STAR Mixture Toxicity, Dynamic-Energy-Budget (DEB) and risk assessment Workshop: The students gained knowledge on principal concepts of concentration addition and independent action for predicting mixture toxicity, their range of applicability and their limitations, an overview of the available designs for a particular mixture toxicity related research question. An in-depth knowledge on the concept of the Dynamic-Energy-Budget theory, and the effects of toxicants and mixture exposure within this theory and concepts on environmental risk assessment approaches in a multiple contaminant context.
- Radiological Protection of the Environment: A professional development training course: The main learning outcome is in radiological environmental assessment focussing on the ERICA Tool. The course giving gives regulators, industry and their representatives knowledge on how to: use available tools; learning to interpret their results; and understand the implications of how the tools are used

3.3. Timing of STAR Course modules

The four STAR courses, and the dates they were completed are:

- One week PhD course on Environmental Radiobiology, held in June 2013
- Two week MSc course on Experimental Radioecology, held in October 2013
- Three day training course in Mixture Toxicity, held in January 2014
- Three day training course in Environmental Protection, will be held in April 2014

4. STAR MSc course in Experimental Radioecology

The MSc course in Experimental Radioecology (KJM351/353) is the STAR "flagship" radioecology course intended to be accessible to students taking other environmental science and radiation related subjects, as well as to professionals wishing to build up their competence. At the present time, the course is held at NMBU (previous UMB) as part of the Radioecology MSc and the CERAD CoE education program, but earlier versions of the course module have been offered to NMBU students since early 1990s.

Two-week courses in radioecology, Radioecology (ECTS 5 points) derived from and given together with Experimental Radioecology (ECTS 10 points) were organized in parallel at the Norwegian University of Life Sciences, NMBU, Aas from October 7th to October 19th 2013. The courses were aimed at MSc and PhD students. The 5 point Radioecology course attracted 7 students while 6 students followed the Experimental Radioecology (ECTS 10 points) course. The teachers were recruited among distinguished lecturers and scientists from Europe and Canada. All the course students were recruited from the Consortium members. Based on the course evaluation questionnaire, direct feedback from students as well as the experience of the teachers, the courses were successful in creating a good pedagogical atmosphere. The accommodation of students in a private house and examinations at the student's home universities also were successful. The course responsible was Associate Professor Ole Christian Lind (NMBU)

4.1. Introduction

In a diverse learning process, the students gained knowledge about radioecology (i.e. source terms, ecosystem transfer and behaviour of radionuclides in the environment), as well as biological effects, impact and risk assessment based on radiochemistry and radiation protection. Case studies include NORM, accidental situations, the nuclear industry and waste management.

Lectures were given by five internal teachers from Norwegian University of Life Sciences (NMBU) and eight external teachers from University College Dublin (UCD), Ireland; IRSN, France; SCK•CEN, Belgium, CIEMAT, Spain; Jožef Stefan Institute (JSI), Slovenia; Norwegian Radiation Protection Authority (NRPA) and University of Oslo (UIO), Norway. A case study dealing with preparedness and countermeasures was arranged by teachers from NMBU/NRPA. Furthermore, 3 technical staff from NMBU supervised laboratory exercises while 1 administrative staff helped organizing travel and accommodation for visiting teachers and students.

For the 2013 courses, 16 students registered and followed the course lectures and laboratory training, while only 13 of these took the exam and passing the full course in the end. The nationality of the students covered Norway (four), Chile (one), Japan (one), Nepal (one), Finland (two), Russia (three) and Germany (one), while they were travelling from Finland, Russia and Belgium.

4.2. Learning environment

The learning is based on several intensive weeks with lectures, laboratory work, group work, real-life case studies and a thematic thesis with an interdisciplinary approach, and through reflection on links between real-life situations and theory. Giving most of the course modules as intensive blocks makes the courses easily accessible for training needs. In this way, the course is open for PhD students, MSc students and trainees from all over Europe. The course curriculum is given in Appendix 1 and 2.

4.3. Adaption made for STAR

Although the course to be offered as part of the STAR project was scheduled for autumn 2013, based on input from the STAR E&T stakeholder workshops and STAR consortium discussions, some changes were already made to the course for 2012. This included addition of other international and STAR specialists from IRSN, McMaster University and NRPA. The 2012 course attracted 10 students, of whom 6 followed the full 10 ECTS course and passed the exam. All the course students were recruited from the Consortium members, with local NMBU students representing 50%. Feedback from the student course evaluation questionnaire, as well as direct response from students and the experience of the teachers, was positive. The only criticism was the high intensity of the lecturing hours, which might be hard to change given the short time frame for an intensive course. The feedback from students and teachers has as far as possible been taken into account for the 2013 course.

Further developments have been made for the 2013 course (held in October 2013). These include increased participation from STAR consortium members: SCK•CEN, CIEMAT, NRPA and IRSN. An overview of the various proposals received from stakeholders and STAR participants is given in STAR deliverable 6.2, together with the proposed changes. The 2013 course lecture plan is provided in Appendix 1.

The main administrative changes made since the start of the STAR project include:

- Splitting into two course modules giving10 ECTS or 5 ECTS in order to better cover the needs of both students and professionals
- Restructuring to give intensive teaching over 2 weeks to allow participants from external universities and international professionals.
- Organization of exam at home university for external students.

4.4. Organization of the course module

The courses were organized in parallel over two week's intensive teaching. The basic outline was alternating between lectures, case study, laboratory demonstrations and laboratory exercises. The theoretical part of the course consisted of 38 hours of lectures and a 4 hours case study (i.e. 42 contact teaching hours) whereas laboratory exercises (23.5 hours) and laboratory demonstrations (1.5 hours) totaled another 25 contact teaching hours.

The external teachers were invited to provide lectures on specific topics and they stayed overnight if possible to have the opportunity to interact with the students in the evenings. Internal teachers were drawn from the staff of Department of Plant and Environmental Sciences, NMBU, Aas.

For detailed description of course organization, see Appendix 1 and 2.

4.5. Theoretical content

Below, the theoretical parts of the Radioecology course module are presented in short.

4.5.1 Sources: Past, present and future sources of radionuclides in the environment

This topic was covered by a 2 hour overview lecture and 2 hours dealing specifically with the Chernobyl and Fukushima accidents. The topic was also covered intrinsically in many other topic lectures. The teachers were Lindis Skipperud (NMBU, Norway), Per Strand (NRPA, Norway) and Hildegarde Vandenhove (SCK•CEN, Belgium).

Content:

- Natural and anthropogenic sources
- Nuclear weapon testing
- Nuclear fuel cycle
- Nuclear accidents
    - Fukushima

- Chernobyl
- Dumping of radioactive waste
- NORM/TENORM
- Orphan sources

4.5.2 Radiochemistry, Separation techniques for environmental samples

This topic was covered by 3 hours of lectures. The teacher was Lindis Skipperud from NMBU, Norway.

Content:

- Sample to analysis
- Radiometric and mass spectrometry methods
- Chemical separation
  - Pre-concentrations
  - Separation by extraction – liquid and solid extraction
  - Ion exchange chromatography
- Interferences

4.5.3 Speciation of radionuclides in the environment - radioecological aspects

This topic was covered by 4 hours of lectures but was also covered intrinsically in many other topic lectures. The teachers were Brit Salbu and Ole Christian Lind both from NMBU, Norway.

Content:

- Definitions
- Physico-chemical forms
- Radioactive particles
- Speciation techniques
- Analytical strategies and techniques

4.5.4 NORM and TENORM

This topic was covered by 4 hours of lectures and calculation exercises. The teachers were Jelena Mrdakovic Popic (NMBU, Norway) and Peter Stegnar (JSI, Slovenia).

Content:

- Public health issues related to Radon
- Sources of contamination of NORM radionuclides with cases:
- NORM sites in Norway
- TENORM sites in Central Asia and Norway
- Dose calculations

4.5.5 Radioecology and countermeasures

This topic was covered by 12 hours of lectures but was also covered intrinsically in many other topic lectures. The teachers were Tom Hinton (IRSN, France), Luis León Vintró (UCD, Ireland), John Brittain (UiO, Norway), Justin Brown (NRPA, Norway) and Lindis Skipperud (NMBU, Norway).

Content:

- Definitions, principles and challenges, including multiple stressors
- Terrestrial radioecology
    - Ecosystem transfer of radionuclides
    - Countermeasures
- Marine radioecology
- Freshwater radioecology

4.5.6 Advanced analytical techniques employed within radioecology

This topic was covered by 2 hours of lectures but was also covered intrinsically in many several other topic lectures. The teacher was Ole Christian Lind from NMBU, Norway.

Content:

- Mass spectrometric (MS) techniques
    - AMS
    - ICP-MS
- Micro-analytical techniques
    - Electron microscopy with x-ray microanalysis
    - Synchrotron based x-ray micro- and nanobeam techniques
    - TOF-SIMS
    - LA-ICPMS
- Fractionation techniques combined with MS techniques

4.5.7 Biological effects

This topic was covered by 5 hours of lectures. The teachers were Deborah Oughton (NMBU, Norway) and Hildegarde Vandenhove (SCK•CEN, Belgium).

Content:

- Biological effects of ionizing radiation to man and non-human biota
    - Principles
    - Mechanisms
    - Biomarkers including bystander effects
- Assessing impacts of ionizing radiation to non-human biota
- Introduction to Erica assessment tool

4.5.8 Modelling within radioecology

This topic was covered by 4 hours of lectures but was also covered in lectures on Fresh water radioecology and Marine radioecology. The teacher was Juan Carlos Mora Canadas from CIEMAT, Spain.

Content:

- Dispersion of radionuclides
- Compartment (box) modelling
- Dose assessment

4.5.9 Nuclear preparedness and environmental security

This topic was covered by 2 hours of lectures and a 4 hours case study. The teachers were Brit Salbu, Per Strand and Ole Christian Lind.

Content:

- Radiation protection regulations at Campus Aas
- National preparedness
- Threat assessment
- Uncertainties
- Risks
- Management
- Concepts
- Environmental security

4.6. Laboratory exercises

Laboratory exercises (23.5 hours) supervised by Marit Pettersen, Merethe Kleiven and Tove Loftaas and demonstrations (electron microscopy; 1.5 hours) given by Ole Christian Lind consisted of 25 contact teaching hours. Laboratory exercises essentially consisted of 2 different mesocosm experiments including fresh water, sediments, biota (macro-invertebrates) and radioactive tracers (^{60}Co, ^{137}Cs). The students worked in groups of 3 or 4 and were trained in the determination of the following parameters:

- Kd
- BCF
- Water soluble, potentially bioavailable, reversibly and irreversibly sorbed as well as inert fractions using sequential extractions
- Percentage distribution of particulate fraction, dissolved fraction, colloidal fraction, low molecular fraction as well as cationic and anionic fractions of radionuclides by means of size and charge fractionation.

The students participating in the Experimental Radioecology course were obliged to submit an in-depth lab journal for which they received (marks; 25% of the total mark for the course), whereas the students participating in the 5 credit Radioecology course, needed only submitting a relatively less exhaustive lab journal (not subjected to marks). All students, submitted good and in some cases very good lab reports and the learning outcome related to writing these reports seems to be quite high.

4.7. Term paper

Students in the Experimental Radioecology course were also obliged to submit a 10-20 pages term paper on a prescribed subject and given title or on a self-elected subject and title.

4.8. Evaluation of the course

Based on a questionnaire answered by the students after the course exam the students thought that the course in all was interesting and good with an average score of 5.88 (where 6 is the best), while lectures scored 5.13 and laboratory practices scored 5.63. The teachers scored on average 5.63 while the course scored 5.75 on communication. The presence of top specialists as teachers and a good mix of lectures and laboratory exercises were highlights of the course.

5. Environmental Radiobiology PhD course

The Environmental Radiobiology course (MINA 410) was the test PhD course run during the STAR project. The aim of the course was to give students an overview of the fundamental principles of radiobiology, but within the context of effects on non-human biota.

5.1. Introduction

In a development from the original STAR workplan, we made a successful application for additional funding from DoReMi for this course, primarily to foster exchange of students between the two disciplines, and also to strengthen links with the radiobiology community. The rational was that the course would provide the opportunity to get a better understanding of the fundamentals of radiobiology for students of radioecology; and that for radiation biology students it would offer the chance to see how radiobiology concepts and tools are applied in other areas of radiation research, thus gaining a more in depth understanding of the subject. Teachers were from Norway, Canada and Sweden and 28 students took the course with a split of 20 PhD and MSc students and 8 “professionals”; of whom 8 were from Norway, 15 EU and 5 non-EU (USA, Argentina, Russia). Nine students took the full ECTS course, including assignment and exam. Attendance certificates were provided for the other participants.

5.2. Organization of the course module

The course covered both the history and the state-of-the-art of our knowledge on the biological effects of radiation on humans, including how recent studies are challenging established paradigms, but concentrated specifically on those issues and applications of most relevance for other organisms (See Appendix 3). This included effects and endpoints

significant for non-human organisms, ways in which radiobiology methods and biomarkers are being applied in ecological research, factors influencing radiosensitivity in different organisms, and ecological risk assessment. Case studies included ecological research in Chernobyl and Fukushima, and laboratory work on biomarker analysis in model organisms. The lecture plan is provided in the Appendix.

The course was mainly lecture based, with one afternoon of laboratory practicals and demonstrations linked to the preparation and analysis of samples for biomarker assessment following in vivo irradiation of whole organisms (fish and earthworms). Teaching also included group discussion exercises and a mock « court case » on use of LNT in low dose risk assessment. In general, the days were split into lectures on radiobiology (Seymour and Wojcik) and ecotoxicology (Mothersill, Bradshaw and Oughton). Teachers were from Norway, Canada and Sweden.

The exam was a course assignment to produce a detailed experimental description and plan for testing a specific hypothesis (topics were chosen by the students and could be related to their own research projects). In addition to the one week intensive teaching, students were expected to spend one week on research and assignment, and were given feedback on outlines by the course teachers during this time.

5.3. Theoretical content

The course module included the following theoretical content:

Radiobiology refresher

- DNA damage and repair mechanisms and assays ; PFGE, comet assay, focus assay (Andrzej Wojcik, SU)
- Cell death mechanisms (mitotic death, apoptosis, autophagy) and biophysical models based on clonogenic cell survival (Colin Seymour)

Assessing the Impacts of Ionising Radiation on Non-human biota

- History, concepts and differences between approaches for non-human species and humans (Deborah Oughton)
- Impact of Ionising Radiation on Non-human biota – challenges from endpoint and effects analysis (Carmel Mothersill)

Factors influencing cell radiosensitivity

- Oxygen status, cell cycle, chromatin, etc (Colin Seymour).
- Mechanisms of extreme radioresistance: Selected non-human species: rotifers, taridgrades, insects, bacteria (Andrzej Wojcik).
- Radiosensitivity and radioresistance in non-human species, intra and interspecies differences, life history stages (Carmel Mothersill)

Biomarker tools and endpoint assessments

- Introduction to biomarkers of exposure – what can they tell us (Andrzej Wojcik)
- Applications in non-human biota:
- Cytogenetic damage (chromosomal aberrations and micronuclei) - the most common biomarkers of exposure;
- Immunohistochemical and bystander assay (Carmel Mothersill)

RBE and weighting factors:

- Comparison of human and non-human approaches;
- Non-targeted effects and new paradigms in radiation biology (Colin Seymour and Carmel Mothersill)

Field studies of radiation ecological effects 3 hrs lectures plus 2 hr group discussion

- Introduction and challenges (Deborah Oughton);
- Cases: Chernobyl, Mayak, Fukushima, mining, waste disposal (Clare Bradshaw and Carmel Mothersill).
- Group work on designing and interpreting field study cases;
- Feedback and summary session

Ecological Risk Assessment and Regulation 4 hrs

- Systems Ecology, Ecosystem Approach and Radiation Ecology (Clare Bradshaw).
- Environmental Risk Assessment and Regulation of Effects on Non-human Species (Deborah Oughton)

Laboratory Demonstrations and Case Studies

Visit to the NMBU low dose irradiation facility, FIGARO. Laboratory work: organism dissection, cell cultures, harvesting for bystander analysis, comet assay, micronuclei assay. Demonstrations and hands on exercises (Mothersill, Turid Hertel Aas, Dag Anders Brede, Bjørn Rosseland, plus NMBU staff)

Exercise: Court Case on Low Dose effects (Colin Seymour)

5.4. Evaluation of the course

The evaluation form was not in the form of a "scoring sheet", but a form where students were asked to comment specifically on the individual lectures and group study sessions, choose the most useful/interesting talks and offer suggestions for improvement of the course. Nearly all lectures were somebody's favourite (with the biomarker and field study cases getting the overall highest scores). General comments included suggestions for including more laboratory training, and an extra introduction day in radiobiology for those coming from outside the field. The social events (Midsummer party, barbeque Tai Chi Session) also received a very favourable feedback.

6. STAR Mixture Toxicity, DEB and risk assessment Workshop

Contaminants never occur in isolation yet legislation is still largely based on effects of single compounds. In addition, more and more data are becoming available that suggest that compounds can exert effects in organisms when present in mixtures in concentration ranges at which the single contaminants do not induce effects. The examination of combined exposures, which corresponds much more realistically to exposure conditions in the environment than the analysis of single substances, entails major methodological difficulties in the experimentation and evaluation procedure.

6.1. Introduction

This workshop organised in the context of the European STAR project (Strategy Towards Allied Radioecology) aimed to introduce some of the approaches and methodologies used in studying and predicting mixture toxicity effects.

This workshop intended to attract Ph.D students and researchers that are now confronted with the challenges of assessing or predicting biological effects in mixed exposures situations. As the general concepts discussed in the workshop apply to different fields of research, the course was open not only for people within the consortium but also to participants for all fields of (eco)toxicology.

The four-day course was organized from the 27th to the 30th of January 2014 at SCK•CEN, Mol, Belgium. The lecturers were recruited specifically to obtain experts in the field. Course participants were partly within the STAR consortium and partly from the broader field of ecotoxicologists. All information including all presentations and exercises were available for the participants and can be offered to others on request. All participants were given a certificate of attendance at the end of the workshop.

6.2. Learning environments

The aim of the workshop was to provide:

- A description of the principal concepts of concentration addition and independent action for predicting mixture toxicity, their range of applicability and their limitations.
- An overview of the available designs for a particular mixture toxicity related research question.
- An overview of ways to address deviations from the existing reference models

- An in-depth knowledge on the concept of the Dynamic-Energy-Budget (DEB) theory, and the effects of toxicants and mixture exposure within this theory.
- Practical statistical approaches to be able to tackle linear and generalised linear modelling and to describe dose-effect relationships
- Concepts on environmental risk assessment approaches in an multiple contaminant context.

The workshop was a fifty-fifty mixture of interactive lessons (12 h) and calculus sessions or case studies (12.5 h) in which the participants were given the opportunity to directly practice the theory. Where necessary, new software, such as "R" and the software to do environmental risk assessment was provided. All used software is freeware that the participants can keep on using after the workshop. The mixture of theory and calculus sessions greatly enhanced the learning process and was well appreciated by the participants.

Lectures were given by five lecturers one from SCK•CEN and two from IRSN, and from out of the consortium one from the Free University-Amsterdam, the Netherlands and one from RIVM, the Netherlands. Furthermore practical organisation of the course and help with travel and accommodation of the visiting lecturers and the participants was offered by the Centre for Education and Knowledge Management of SCK•CEN and by technical staff.

In total 9 participants from 6 different countries enrolled, two students from Belgium, Three students from Norway, one from Italy, one from South-Chorea, one from Austria and one student from France. The course was attended by PhD students as well as post-doctoral scientists. Only 1/3 of the participants were from the consortium members, others came from research institutes, universities or private companies.

6.3. Adaptation specifically for STAR

A similar course was given by SCK•CEN and IRSN in September 2010 as part of the IAEA-EMRAS-II-Biota Effects working group. Compared to the present workshop, the 2010-course focussed completely on mixture toxicity. To adapt the course to the needs of STAR a full day was added on risk assessment. Techniques and approaches explained and learned in this workshop such as dose-response modelling, investigating interaction between toxicants, risk assessment of multiple polluted sites are directly applicable for the work performed in WP4 and WP5 of STAR.

6.4. Organisation of the course

The workshop was divided in different modules subsequently addressing, dose response modelling, mixture toxicity approaches such as concentration addition and independent action, dynamic energy budget modelling and risk assessment with speices sensitivities distributions. An overview of the topics handled in each of these modules is given below.

Dose-effect modelling in R, Clair Della Vedova, IRSN, France, 1h theory, 2h calculus

The analysis and the modelling of monotonic dose-response relationships is presented. Some theoretical elements are first given, and then practical modelling is displayed with the 'drc' add-on package of R software.

Short introduction to Multiple stressor research, Nele Horemans, SCK•CEN, Belgium, 1h theory

This part of the course introduces the need of being able to assess the effects of pollutants in a multi-contaminant context from effects observed in a single stressor situation. The specific issues that should be addressed when dealing with multiple stressors are also introduced.

Concepts of concentration addition (CA) and independent action (IA) Nele Horemans, SCK•CEN, Belgium, 2h theory

Here the tools most often used to assess effects of mixtures based on single stressor toxicity data namely, the Concentration Addition (CA) and Independent Action (IA) models are introduced. Both are descriptive models based on the similarity or dissimilarity in mode of action of the toxicants and use effects data of single compounds to predict effects of mixtures.

Experimental design, Nele Horemans, SCK•CEN, Belgium, 1h theory

As both CA and IA depend on effects data, an overview is first given on the strengths and weaknesses of the different experimental designs. Furthermore attention is given to the reproducibility of toxicity data and the dependence on the tested endpoint.

Deviations from Concentration Addition (CA) and Independent Action (IA), Nele Horemans, SCK•CEN, Belgium, Claus Svendsen, Centre for Hydrology and Ecology, United Kingdom, 2h theory, 1h calculus

Both concepts of CA and IA are based on the assumption that the chemicals in the mixture do not affect the biological activity of the other chemicals in the mixture. However, the measured response of the mixture can deviate markedly from the expected response based on the reference models. When the measured response is greater than expected, the response is said to be synergistic. The term antagonistic is used when the measured response is lower than expected. However, more complex response patterns occur depending on the dose level or dose ratio of the different toxicants.

Calculus session on predicting deviations from CA and IA, Nele Horemans, SCK•CEN, Belgium, Claus Svendsen, Centre for Hydrology and Ecology, United Kingdom, 2,5h case studies

Using a case study the participants are asked to predict the effect of a mixture using the concepts of CA and IA. Examples of deviations of mixture toxicity are also be studied. The

"mixtox model" described by Jonker et al. 2005 is used to predict deviations of CA or IA in a case study.

Introducing Dynamic Energy Budget (DEB) and DEBtox theory and modelling, Tjalling Jager, Free University of Amsterdam, The Netherlands, 2h theory

In this part of the course an introduction is given to Dynamic Engergy Budget (DEB) theory, a biological theory with applications in ecotoxicology. The DEB-theory explains how organisms acquire and use recourses over their life cycle, based on a set of simple rules for metabolic organization. Toxicant effects are treated as a disruption of regular metabolic processes such as an increase in maintenance costs, which leads to dynamic effects on life-history traits.

A practical application of the simplified DEBtox equations to the case of Daphnia exposed to Uranium, Fréderic Alonzo, IRSN, France, 3,5h calculus

This part of the course focussed on a practical approach to DEB. This included:

- Modeling growth and reproduction in the unexposed organism;
- Applying a toxic stress using the different modes of action in exposed organisms;
- Fitting DEBtox "physiological" and toxico-kinetic parameters to the control and exposed datasets;
- Build a confidence interval for the parameters and outputs (bootstrap technique).

General introduction to risk assessment and compound-oriented risk assessment and deriving and using Environmental Quality Criteria, Leo Posthuma, RIVM, The Netherlands, 1h theory

This part of the course gives and introduction to the principles and practices of risk assessment. Risk assessment is triggered by a societal, practical problem, and the expectation is that the risk assessor helps to solve that problem. Before using it by the participants on a realistic problem, there is an interactive and critical introduction to the general approaches of risk assessment, with emphasis on ecological risk assessment, and within that on that of mixtures in the real world.

Introduction to Species Sensitivity Distributions and to quantitative mixture risk assessment using SSD's, Leo Posthuma, RIVM, The Netherlands, 1,5h theory

One method, Species Sensitivity Distributions (SSD) modeling combined with mixture assessment is used to quantify the fraction of species in the field that is likely affected - which is (at least) a relative estimate of hazard: "this exposed site is worse than that regarding impacts", whilst such a ranking can be of great help in decision-making and priority setting of remedial or preventive actions. Impacts at the level of whole species assemblages are relevant in the context of UN-adopted concepts like "Ecosystem Services" (such as food production, etc.).

Mixture risk, multiple stress and effects at ecosystem level: interactive reflections and contemporary developments, Leo Posthuma, RIVM, The Netherlands, 1,5 theory

Knowing all techniques for mixtures at the level of tests, modelling and risk assessment now, one next step is the assessment of the situation on a landscape scale. There are other stressors too, next to mixtures. Eco-epidemiological analyses of (bio)monitoring data and other approaches will be presented and discussed, to complement and validate the risk assessments.

ERA | Practical, Leo Posthuma, RIVM, The Netherlands, 3,5h case studies

Risk assessment practices with SSDs are illustrated via the formulation of a hands-on, realistic contamination problem. Via the use of risk assessment software, specifically designed for SSD-modelling, the participants will experience not only the techniques used, but also what it means to use such techniques at the science-policy interface. The problems are often not so simple as they appear.

6.5. Evaluation of the course

Feed-back on the course was given through a questionnaire and directly by the participants and teachers. In general participants were very satisfied with the concept and the organisation of the course. The general judgement has been quoted as “excellent” (7/9) & “good” (2/9).

7. Radiological Protection of the Environment - a professional development training course

Under funding from the Natural Environment Research Council, STAR partners NERC-CEH, IRSN and SCK•CEN together with the University of Stirling, developed and ran a number of training course on radiological environmental assessment focussing on the ERICA Tool (course materials and feedback can be found on https://wiki.ceh.ac.uk/x/dIPJBg). These training courses have been further developed and will be run as part of the STAR project. The courses are primarily aimed at regulators and industry, and those who may conduct assessments on their behalf. However, the course is also open to PhD. students and other researchers.

The course is structured such that Day 1 will provide a basic grounding and Days 2 & 3 will go into more detail. The objectives are to ensure participants are:

- conversant with assessment objectives
- have a basic understanding of radionuclide transfer, dosimetry and radiation effects
- know how to use the available tools & can interpret the resultsunderstand the implications of how the tools are used

Practical sessions are run on each aspect of the assessment process covered in lectures.

The course will be run 1-3 April 2014 with 17 participants confirmed (course limit is20). Briefing notes have been prepared to provide participants a basic overview of each topic area covered during the course which also provides key references for further reading. These documents are open-access documents and are available on-line:

- Introduction to environmental radiation protection
- Transfer models within radiological environmental assessment tools
- Radiation effects on plants and animals
- Setting and using benchmarks in radiological assessments of the environment
- Dispersion modelling: ERICA methodology and optional alternatives
- Radiation dosimetry for animals and plants
- Updates to the ERICA Tool - version to be released 2014

The course programme will be as follows:

Tuesday 1st April 2014

Registration & buffet lunch available

Course outline

Introductions

Radiological protection of the environment – international context

ERICA Tool introduction

ERICA Tool Tier 1 – practical

Transfer - estimating radionuclide activity concentrations in wildlife

Transfer in the ERICA Tool – practical

Course dinner

Wednesday 2nd April 2014

Dosimetry

Dosimetry in the ERICA Tool demonstration & practical

Radiation effects

Numerical benchmarks

Demonstration & practical - benchmarks & effects

Practical - Assessing a marine discharge

Thursday 3rd April 2014

Dispersion modelling

How to model atmospheric noble gas releases

Practical: Terrestrial assessment

What to look for when interpreting an assessment

Course round-up and feedback from participants

Optional session on RESRADBiota

Course lecturers will be:

Dr. Brenda Howard (CEH Lancaster)

Dr. Nick Beresford (CEH Lancaster)

Dr. David Copplestone (Stirling University)

Prof. Jordi Vives i Batlle (SCK•CEN, Belgium)

In addition STAR participants Dr. Tom Hinton (IRSN Cadarache, France) and Justin Brown (NRPA) have prepared course and/or background reading materials. Subsequent to the course presentations and feedback will be published on-line.

Additionally, a ½ day refresher to cover updates to the ERICA Tool that are due to be released later this year will be held once a delivery date for the Tool is confirmed. This session will be aimed at previous course attendees and current experienced users (19 people have registered an interest in attending; predominantly regulators with some consultants/industry representatives).

8. Environmental Radioactivity Modelling Module

A clear recommendation from the E&T stakeholder workshops was the need for modelling competence. There was strong consensus from STAR partners that this is an important area of expertise, and one that is highly sought after in stakeholders and employers. Funding and resources to set up a whole new module has not been included in the STAR budget, but it was agreed that efforts should be made to start the process to "fill the hole", with a view to looking at eventual financing and feasibility, and possibilities for follow up. Thus CIEMAT and SCK•CEN have started to put together a module outline, and there is positive feedback that such a module could be offered at the University of Madrid.

Briefly, this is a module that would attract professionals as well as students and also lends itself well to distance and e-learning. It should be relatively cheap compared to laboratory courses. Learning goals would include that students would be able to use simple assessment models (via hands on training in some models), that they would be able to understand the

applications, assumptions and limitations of models, and that the course would provide the basic competence to go on to take a PhD in modelling (i.e., the aim is NOT to produce fully fledged modellers in two weeks).

Potential funding opportunities were also discussed, including the possibility of links with DoReMi or NERIS training courses, as well as an Alliance sponsored professor at the host university. These will be discussed further in Deliverable 6.4.

References

Skipperud, L., Salbu, B., Priest, N. D., Garelick, H., Tamponnet, C., Abbott, A. & Mitchell, P. (2011). European MSc programs in nuclear sciences: to meet the need of stakeholders. *Nuclear Engineering and Design*, 241 (4): 1013-1017.

Appendix 1: Experimental Radioecology MSc Courses - invitation and plans

First Announcement and Registration

CERAD CoE and STAR Courses

"RADIOECOLOGY" (5 ECTS) AND "EXPERIMENTAL RADIOECOLOGY" (10 ECTS)

At

Centre for Environmental Radioactivity
Norwegian University of Life Sciences

Ås, Norway

7 - 18 October 2013

Organised by Centre for Environmental Radioactivity,
Norwegian University of Life Sciences (UMB)

in cooperation with

Strategy for Allied Radioecology (STAR) network of excellence (NoE)

Hosted by Centre for Environmental Radioactivity,
Norwegian University of Life Sciences

Fougnerbakken 1, 1430 Ås, Norway

Background

The ultimate aim of the education and training part of STAR is to ensure a sustainable workforce in radioecology. To do this we are dependent on interactions with the wider radioecology community, through outreach out to students, teachers, employers and employees, and other stakeholders outside of the STAR network.

Since radioecology is a multidisciplinary science, students on MSc or PhD projects in radioecology have a wide range of future carrier opportunities, and one of our goals is to put students in contact with potential employers and research projects, as well as to ensure that training and education in radioecology meets the needs of those employers.

STAR will hold a number of courses during the lifetime of the project, ranging from MSc and PhD courses to workshops and worker training. The majority of these courses will also be open to participants outside STAR.

The **"Radioecology" and "Experimental Radioecology"**

courses are arranged in cooperation with STAR and are open to MSc and PhD students.

Scope and Objectives

After the course the students should have an overview over radioecology and be able to conduct experimental radioecological studies. In order to accomplish this they will acquire knowledge of:

- Radioactive sources and understand the transport of radioactive substances in various ecosystems with special focus on physico-chemical forms (speciation) and their influence on mobility and biological uptake
- The basis for environmental impact and risk assessments and be able to conduct radioecological studies using tracer techniques, radiochemical separation techniques and advanced measurement methods
- Environmental impact and risk assessments and the use of effective countermeasures, i.e. competence that is needed within national preparedness associated with radioactive contamination
- How to prepare and deliver effective oral and written presentations of technical information and scientific results.

The students will learn to think critically and solve complex and multidisciplinary problems, as well as learn to accurately interpret current research literature.

Course description

The courses run in parallel over 2 weeks (Oct. 7th- 18th) at UMB, Aas (30 min by train South of Oslo), Norway. Lectures and 4 laboratory exercises are the same for the 2 courses.

The „Radioecology“ gives 5 ECTS andrequires participation in the laboratory work and delivery of a short laboratory report only. The course „Experimental Radioecology“ gives 10 ECTS and includes an extensive lab report as well as a a term paper to be delivered.

A written exam will be held at the end of semester, usually early or medio December. It is usually possible to arrange for the students to take the exam at their home institutions.

Course topics

- Sources: Past, present and future sources of radionuclides in the environment
- Radiochemistry and nucear forensics
- Speciation of radionuclides in the environment - radioecological aspects
- NORM and TENORM
- Radioecology
- Advanced analytical techniques employed within radioecology
- Biological effects
- Modeling within radioecology
- Nuclear preparedness and environmental security

Target Audience

The main target group will be not only the doctoral students and research workers, but also students at the master level. Including these students into the system should increase attractiveness of the studies of nuclear chemistry and thus enlarge the source of highly qualified professionals for the future employers.

Condition for participation

In order to apply for admission to join the courses through the EU STAR project please use the attached registration form or contact Ole Christian Lind (olelin@umb.no) to obtain a registration form. Pre-Registration/Intention to participate deadline is June 27th.

The number of students will be limited– maximum 16 students.

Date and Venue

The course will take place from 7th to 18th of October 2013 at Centre for Environmental Radioactivity, Norwegian University of Life Sciences, Fougnerbakken 1, 1430 Ås, Norway.

Accommodation

Rooms at Campus Aas, 30 km South of Oslo or in nearby hotels. If accommodation (student housing) is needed, please contact mirian.wangen@umb.no as soon as possible.

Working language of the course will be English.

Fee

There will be no registration fee.

Participants are expected to cover their own travel and subsistence costs.

Training course participation is limited to a maximum of **16** participants and pre-registration is required.

Important dates:

Pre-Registration/Intention to participate deadline:	**June 27th, 2013**
Final confirmation on participation	**September 1st, 2013**
Request for cheap accommodation	**September 1st, 2013**
Training course:	**October 7-18, 2013**

Contact & Information

Scientific co-ordination and registration	For accommodation and travel information
Ole Christian Lind CERAD ✆ + 47 92432406 e-mail : olelin@umb.no	**Mirian Wangen** CERAD ✆ + 47 64965540 e-mail : mirian.wangen@umb.no

REGISTRATION FORM

CERAD and STAR Courses

"RADIOECOLOGY" AND "EXPERIMENTAL RADIOECOLOGY"

At

Centre for Environmental Radioactivity,

Norwegian University of Life Sciences

Fougnerbakken 1, 1430 Ås, Norway

7 - 18 October 2013

Organised by Centre for Environmental Radioactivity, Norwegian University of Life Sciences

in cooperation with

STAR

Participants can register by completing the following form and submitting to Ole Christian Lind (olelin@umb.no) not later than October 1st, 2013.

I want to participate in the [ ] full Experimental Radioecology course (10 ECTS)	
I want to participate in the [ ] short Radioecology course (5 ECTS)	
Surname	
First name	

Institute and mail address	
[ ] I apply for accommodation booking in apartment during the course term	Day of arrival: Day of departure:

Appendix 2: Experimental Radioecology MSc Courses Final Program

Final Programme for KJM351/KJM353 Experimental Radioecology/Radioecology 2013

KJM351 Experimental Radioecology 10 points

KJM353 Radioecology 5 points

Lab exercises at the Isotope laboratory

Lunch break usually between 1200-1315 (see detailed programme)

The module include the following:

Ca. 38 hours lectures, 4 hours case study

Laboratory practice (ca 25 hours) and submission of laboratory journals.

Submission of term paper (only for KJM351).

Written exam in December.

Week	Date	Time	Room	Subject	Lecturer/supervisor
40	Monday 7.10	08:15-10:00 10:15-11:00 11:15-12:00 13:15-14:00 14:15-16:00	SKP	Introduction: Speciation of radionuclides in the environment, radioecological aspects Introduction to laboratory exercise Radiochemical separation techniques Radiochemical separation techniques cont. Advanced methods	Brit Salbu Marit N. Pettersen Lindis Skipperud Ole Christian Lind
	Tuesday 8.10	08:15-10:00	LAB	Start experiment: Kinetics, CF, Kd. Size- and charge fractionation	Marit Nandrup Pettersen/Merethe Kleiven/Tove Loftaas
		10:15-12:00	PL203	Sources; Past, present and future sources of radionuclides in the environment	Ole Christian Lind
		13:15-15:00	LAB	Kinetics, CF, Kd: 3-4 hrs measurement Size- and charge fractionation continue	M. N. Pettersen/M. Kleiven/T. Loftaas

		15:15-16:45 16:45-17:15 17:15-18:00	PL203	NORM and dose calculations Food/refreshment break Demonstration of radon measurements	Peter Stegnar Peter Stegnar
	Wednesday 9.10	08:15–12:00	LAB	Sequential extractions, step 1-4 Kinetics, CF, Kd: ~24 hrs measurement	M. N. Pettersen/M. Kleiven/T. Loftaas
		13:15-14:00 14:15-15:00	J106	Demonstration of the NRPA preparedness mobile laboratory The Chernobyl nuclear accident	Per Strand/Bjørn Lind Per Strand
		15:15-16:00	LAB	Sequential extractions, end step 4	M. N. Pettersen/M. Kleiven/T. Loftaas
	Thursday 10.10	08:15–12:00	LAB	Sequential extractions, step 5-6	M. N. Pettersen/M. Kleiven/T. Loftaas
		13:15-16:00 16:00:-16:30 16:30-17:15	SU113	Modeling within radioecology (**NB! students need laptop pc**) Food/refreshment break Modeling within radioecology	Juan Carlos Mora Canadas Juan Carlos Mora Canadas
	Friday 11.10	08:15-11:00	LAB	End kinetics, BC, Kd, ~70 hrs measurement Autoradiography Start depuration	M. N. Pettersen/M. Kleiven/T. Loftaas
		12:00-14:00 14:15-15:45	Curie/Image centre	Radioactive particles/Speciation Electron microscopy/Particle identification and characterization (demonstration)	Ole Christian Lind Ole Christian Lind/Cato Wendel
	Saturday	~1230-~1630		Joint tour to the Bygdøy museums, Oslo (Kon-Tiki, Fram, Viking ships)	Ole Christian Lind
41	Monday 14.10	09:15–11:30 12:15-15:00	LAB	End depuration. Size- and charge fractionations, ~96 hrs Autoradiography (read-out)	M. N. Pettersen/M. Kleiven/T. Loftaas /O. C. Lind
		15:15-16:00 16:15-17:00 17:00-17:30 17:30-18:15	J106	Biological effects of ionizing radiation Uptake of radionuclides in plants Food/refreshment break, Isotope laboratory Biological effects of ionizing radiation in plants	Deborah Oughton Hildegarde Vandehove Hildegarde Vandenhove

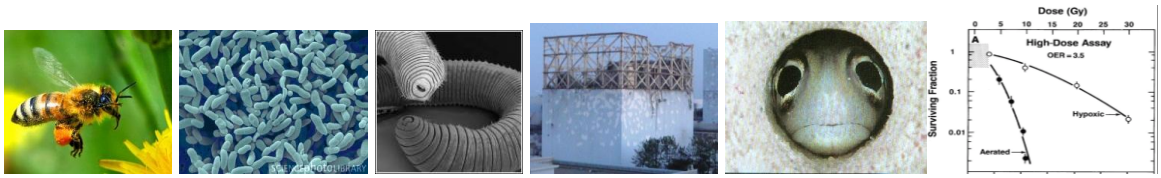
	Tuesday 15.10	09:15–10:00 10:15-12:00 13:15-15:00 15:15-16:00 16:00-16:30 16:30-17:15	SKP	The Fukushima accident Freshwater radioecology including modeling Assessing impacts of ionizing radiation to man and non-human biota (principles, mechanisms, biomarkers) Radioecology principles and challenges, including multiple stressors Food/refreshment break Radioecology principles and challenges, including multiple stressors	Hildegarde Vandenhove John Brittain Deborah Oughton Tom Hinton Tom Hinton
	Wednesday 16.10	09:15-11:00 11:15–12:00 13:15–15:00	SKP	Radioecology principles and challenges, including multiple stressors cont. Radionuclides in the marine environment Radionuclides in the marine environment cont.	Tom Hinton Luis León Vintró Luis León Vintró
		15:15-16:00	DEMO	Visit to FIGARO “Facility for Low Dose-Rate Gamma Irradiation”	Ole Christian Lind
	Thursday 17.10	09:15–12:00 13:15-15:00	PL203	Terrestrial radioecology, transfer and countermeasures Preparedness, Environmental security	Justin Brown Brit Salbu
	Friday 18.10	09:15-12:00 13:15-14:00 14:15-15:00	PL203	Case study: Nuclear preparedness Summary of case study Summary of KJM351	Per Strand/Ole C. Lind Per Strand/Ole C. Lind Brit Salbu/Ole C. Lind

Appendix 3: Environmental Radiobiology PhD Course Plan

Environmental Radiobiology

24-28th June 2013, UMB, Norway

5 ECTS MSc/PhD Course organised by the Norwegian University of Life Sciences (UMB) and Stockholm University, supported by DoReMi and STAR



Lecture Plan

All lectures will be held in the SKP Auditorium (Building 61). Lunch will be organised at the SKP canteen or garden.

Overview

The course is mainly lecture based, with one afternoon of laboratory practicals and demonstrations linked to the preparation and analysis of samples for biomarker assessment following in vivo irradiation of whole organisms (fish and earthworms). In general, the days are split into lectures on radiobiology (Seymour and Wojcik) and ecotoxicology (Mothersill, Bradshaw and Oughton).

Monday 24th

0830-0900: Registration and coffee

0900-0920: Welcome from Professor Brit Salbu, Head of the Centre for Environmental Radioactivity (CERAD), UMB

Radiobiology refresher

0920-1030: DNA damage and repair: mechanisms and assays (PFGE, comet assay, focus assay) (Andrzej Wojcik)

1100-1215: Cell death mechanisms (mitotic death, apoptosis, autophagy) and biophysical models based on clonogenic cell survival (Colin Seymour)

Lunch and student registration for those taking the ECTS course

Assessing the Impacts of Ionising Radiation on Non-human biota

1315-1430 History, concepts and differences between approaches for non-human species and humans (Deborah Oughton)

1500-1615 Impact of Ionising Radiation on Non-human biota – challenges from endpoint and effects analysis (Carmel Mothersill)

1700: Social Event: Pizza and beer/soda get-together (Bioteknologibygningen Library, Building 44)

Tuesday 25th

Factors influencing cell radiosensitivity

0915-1030: Common factors influencing cell radiosensitivity - focus on oxygen status, cell cycle, chromatin, etc. (Colin Seymour)

1100-1215: Mechanisms of extreme radioresistance of selected non-human species (rotifers, taridgrades, insects, bacteria) (Andrzej Wojcik)

Lunch

1315-1615: Radiosensitivity and radioresistance in non-human species, intra and interspecies differences, life history stages. (Carmel Mothersill)

Wednesday 26th

Biomarker tools and endpoint assessments, applications in non-human biota

0915-1215; Introduction to biomarkers of exposure – what can they tell us

Cytogenetic damage (chromosomal aberrations and micronuclei) – the most common biomarkers of exposure (Andrzej Wojcik) immunohistochemical and bystander assay (Carmel Mothersill)

Lunch

1315-1615: Visit to the UMB low dose irradiation facility, FIGARO. Laboratory work: organism dissection, cell cultures, harvesting for bystander analysis, comet assay, micronuclei assay. Demonstrations and hands on exercises

1800: Social Event: Tai Chi session followed by "Midsummer" Barbeque (location dependent on the weather!)

Thursday 27th

0915-1215: RBE and weighting factors: comparison of human and non-human approaches; Non-targeted effects and new paradigms in radiation biology (Carmel Mothersill and Colin Seymour)

Lunch

1315-1500: Systems Ecology, Ecosystem Approach and Radiation Ecology (Clare Bradshaw)

1515-1600: Introduction to field studies (Deborah Oughton)

Friday 28th

0915-1100: Field studies of radiation ecological effects: Cases: Chernobyl, Mayak, Fukushima, mining, waste disposal (Clare Bradshaw and Carmel Mothersill)

1115-1200: Group discussions on interpreting field study cases

1200-1215: Feedback and summary session

Lunch

1315-1415: Environmental Risk Assessment and Regulation of Effects on Non-human Species (Deborah Oughton)

1430-1530: Follow up on laboratory sample preparation(Carmel Mothersill)

Examination

The exam is a course assignment to produce a detailed experimental description and plan for testing a specific hypothesis (topics to be chosen by the students and can be related to their own research projects). In addition to the one week intensive teaching, students are expected to spend one week on research and assignment, and will be given tutoring (distance) by the course teachers during this time.

Coffee, Lunch and Social Events

Coffee/tea and a simple lunch will be provided free of charge by UMB. Refreshments at the social events on Monday and Wednesday will be provided by the STAR/UMB Research School.

Teaching Material

Course teaching material in the form of powerpoint presentations and background literature will be provided as pdf files by the organisers.

Appendix 4 Final programme of Mixture toxicity, Biotic ligand model and Risk Assessment course

Monday January 27, 2014

12:30 h	Opening & registration
13:20 h	Welcome *Hildegarde Vandenhove, SCK•CEN, Mol, Belgium*
13:30 h	Dose-effect modelling in R *Clair Della Vedova, IRSN, France*
16:45 h	Wrap up of the first day
17:30 h	Reception & walking dinner

Tuesday January 28, 2014

08:30 h	Short introduction to Multiple stressor research *Nele Horemans, SCK•CEN, Mol, Belgium*
09:30 h	Concepts of concentration addition (CA) and independent action (IA) *Nele Horemans, SCK•CEN, Mol, Belgium*
11:15 h	Experimental design and deviations of reference models *Nele Horemans, SCK•CEN, Mol, Belgium*
14:00 h	Deviations from Concentration Addition and Independent Action *Nele Horemans SCK•CEN and Claus Svendsen, Centre for Hydrology and Ecology, United Kingdom*
17:30 h	Wrap up of the second day

Wednesday January 29, 2014

08:30 h	Calculus session *Nele Horemans, SCK•CEN, Mol, Belgium & Claus Svendsen, Centre for Hydrology and Ecology, UK*
11:00 h	Introducing DEB and DEBtox theory and modelling

	Tjalling Jager, Free University of Amsterdam, The Netherlands
14:00 h	A practical application of the simplified DEBtox equations to the case of Daphnia exposed to Uranium *Fréderic Alonzo, IRSN, France*
17:00 h	Wrap up of the third day
18:00 h	Dinner

Thursday January 30, 2014

09:00 h	General introduction to risk assessment and compound-oriented risk assessment and deriving and using Environmental Quality Criteria *Leo Posthuma, RIVM, The Netherlands*
10:00 h	Introduction to Species Sensitivity Distributions and to quantitative mixture risk assessment using SDD's *Leo Posthuma, RIVM, The Netherlands*
11:00 h	Mixture risk, multiple stress and effects at ecosystem level: interactive reflections and developments *Leo Posthuma, RIVM, The Netherlands*
13:00 h	ERA | Practical *Leo Posthuma, RIVM, The Netherlands*
16:00 h	Wrapping up and feedback of the training course