EUROPEAN COMMISSION

Community research

STAR

(Contract Number: Fission-2010-3.5.1-269672)

DELIVERABLE (D-N°1.12)

Performance Report: final report

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Reporting period: 01/02/14 – 31/07/15

Date of issue of this report: 29/07/2015

Start date of project: 01/02/2011 Duration: 54 Months

STAR

STRATEGY FOR ALLIED RADIOECOLOGY

EURATOM

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Project co-funded by the European Commission under the Seventh Euratom Framework Programme for Nuclear Research &Training Activities (2007-2011)		
Dissemination Level		
PU	Public	PU
RE	Restricted to a group specified by the partners of the [STAR]	
CO	Confidential, only for partners of the [STAR] project	

List of Acronyms and Abbreviations

ALLIANCE:	European Radioecological Alliance. A European Research Platform, in accordance with relevant European Union policies which coordinates and promotes research on radioecology
BLM:	Biotic Ligand Model
CA:	Concentration Addition
CEZ:	Chernobyl Exclusion Zone
CINCH:	Cooperation in education and training In Nuclear Chemistry – Coordination Action
COMET:	Coordination and iMplementation of a pan-European instrument for radioecology. An EC-funded project designed to further the work of STAR and to bring radioecology within the OPERRA radiation protection programme established by the EC's next funding framework: Horizon2020
CONCERT:	European Joint Programme for the Integration of Radiation Protection Research. A Co-fund action.
CROM:	Screening Code for the Assessment of the Radiological Impact of Discharges in Humans
CROMERICA:	Computer code implementing an integrated screening model for humans and wildlife (consistent combination of CROM and Tier 2 of the ERICA Assessment Tool).
DEB:	Dynamic Energy Budget
DEBtox:	Dynamic Energy Budget model that accounts for toxicants effects
DNA:	Deoxyribo Nucleic Acid
DoReMi:	Low Dose Research towards Multidisciplinary Integration. An EC-funded Network of Excellence in radiation biology under the MELODI framework
DoW:	Description of Work
EAB:	External Advisory Board
E&T:	Education and Training
EC:	European Commission
EC_{50}:	Effective Concentration (that induces 50 % of effect)
EJP:	European Joint Programming
ENEN:	European Nuclear Education Network

ERA:	Ecological Risk Assessments
ERICA:	FP6 EURATOM funded project Environmental Risk from Ionising Contaminants: Assessment and Management.
ERICA-Tool:	Assessment model resulting from ERICA project
EURADOS:	European Platform on dosimetry.
EUrays:	European Radiation Research for Young Scientists
EUTERP:	European Training and Education in Radiation Protection Foundation
EUTRAP:	Framework Research Project "EU Trade Policy" - European Parliament
FEP:	Features Events Processes analysis
GIG:	Glowny Instytut Gornictwa, Poland
H2020:	Horizon2020
HERCA:	Heads of the European Radiological protection Competent Authorities. A voluntary association in which the Heads of Radiation Protection Authorities work together to identify common issues and propose practical solutions for these issues
IA:	Independent Action
IAEA:	International Atomic Energy Agency
ICOBTE:	International Conference on the Biogeochemistry of Trace Elements
ICRER:	International Conference on Radioecology and Environmental Radioactivity
ICRP:	International Commission on Radiological Protection
IM:	Interaction Matrix
IUR:	International Union of Radioecology
LC_{50}:	Lethal Concentration 50 (Concentration that induces 50 % of lethality)
MELODI:	Multidisciplinary European Low Dose Initiative. A European Platform dedicated to low dose radiation risk research
MIXTOX:	Model for binary mixture toxicity analysis using reference models such as CA and IA under a user friendly Excel format
MODARIA:	Modelling and Data for Radiological Impact Assessments. IAEA Programme on radioecological assessment and modelling
MoU:	Memorandum of Understanding
MT:	Management Team
NCORE:	National Center for Radioecology of the USA
NEA:	Nuclear Energy Agency

NERIS:	European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery
NSFS:	Norwegian Society for Radiation Protection
NGO:	Non-Governmental Organisations
NoE:	Network of Excellence
NORM:	Naturally-Ocuring Radioactive Materials
OECD:	Organisation for Economic Co-operation and Development – Nuclear Energy Agency
OPERRA:	Open Project for European Radiation Research Area
RadEx:	Radioecology Exchange
RTD:	Research and Technology Development
SC:	STAR's Steering Committee
SETAC:	Society of Environmental Toxicology and Chemistry
SRA:	Strategic Research Agenda
SRS:	Safety Reports Series
SSM:	Sweden Radiation Safety Authority
STAR:	Strategy for Allied Radioecology. An EC-funded Network of Excellence in radioecology under the Radioecology Alliance framework
TKTD:	Toxicokinetic Toxicodynamic
TRS:	Technical Report Series
UNSCEAR:	United Nations Scientific committee on the Effects of Atomic Radiation
USCB:	Upper Silesian Coal Basin
WG:	Working Group
WP:	Work Package

BfS:	German Federal Office for Radiation Protection, Germany
CIEMAT:	Research Centre in Energy, Environment and Technology, Spain
IRSN:	French Institute of Radiation Protection and Nuclear Safety, France
NERC-CEH:	Natural Environment Research Councils Centre for Ecology & Hydrology, United Kingdom
NRPA:	Norwegian Radiation Protection Authority, Norway
NMBU:	Norwegian University of Life Sciences, Norway
SCK•CEN:	Belgian Nuclear Research Centre, Belgium

STUK:	Radiation and Nuclear Safety Authority, Finland
SU:	Stockholm University, Sweden
SUNY:	The research foundation of State University of New York, United States of America
TOKAI:	Tokai University Educational System, Japan

Executive Summary

STAR (Strategy for Allied Radioecology) is a Network of Excellence (NoE) in Radioecology funded under the EC's 7th programme, dedicated to strengthening the science of radioecology in Europe. The Performance Report constitutes the final report of evaluation of the STAR project progress. The first section is the "Final Evaluation Report" produced by the External Advisor Board of STAR. The second section is the review of the Performance Indicators initially proposed in the STAR DoW. Because the STAR project is coming to its end, the evaluation is assessed for the entire period of STAR (and not only the last 18-month of the project).

Overall, STAR reaches all its initial objectives. STAR has made considerable progress in enhancing the long term stability and sustainability of radioecology in Europe. The collaborative work and joint research done has strengthened radioecology and enabled us to achieve the goals set together. Integration was managed even further than imagined in the beginning of the project.

The EAB evaluation of STAR reflects this success since they commented in their report that *"Overall, the EAB is very positive about the accomplishments and European added value of STAR. The EAB is certain that STAR has increased interest and awareness about radioecological issues in the European Community and beyond strengthening future scientific excellence and societal relevance on this important topic."*

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1 Introduction

This document is a Performance Report of the STAR project for the third 18 month period of work, from 1 February 2014 to 31 July 2015, however it covers the full period of the project as a final deliverable. STAR (Strategy for Allied Radioecology) is a Network of Excellence (NoE) in Radioecology funded under the EC's 7th framework, STAR is a consortium dedicated to strengthening the science of radioecology in Europe, initially composed of nine partners and further expanding to eleven partners (Table 1).

Table 1. Partners within the STAR Network of Excellence after integration of the STAR call winners

Partner name	Abbreviation	Country
Institute of Radioprotection and Nuclear Safety	IRSN	France
Radiation and Nuclear Safety Authority	STUK	Finland
Belgian Nuclear Research Centre	SCK•CEN	Belgium
Natural Environmental Research Council	NERC	United Kingdom
Research Centre in Energy, Environment and Technology	CIEMAT	Spain
Stockholm University	SU	Sweden,
Federal Office of Radiation Protection	BfS	Germany
Norwegian Radiation Protection Authority	NRPA	Norway
University of Life Sciences	*NMBU	Norway
Research foundation of State University of New York	SUNY	United States
Tokai University Educational System	TOKAI	Japan

* formerly UMB

STAR is composed of seven work packages (WPs) that focus on coordination of the NoE (WP-1); integration among the partners and developing a strategy for long-term sustainability of radioecology (WP-2); research (WPs -3, -4 and -5); education (WP-6); and knowledge dissemination (WP-7). Details about the NoE and individual WPs can be found on STAR's website (www.star-radioecology.org).

1.1 The External Advisory Board

The evaluation of the STAR project has relied throughout the project on an External Advisory Board (EAB) accompanying the coordinator and the WP leaders.

The STAR EAB, as approved by the EC, was composed of seven experts (Table 2). The board members were chosen based on their expertise relative to seven categories of activities conducted by the various WPs within STAR:

- Risk assessment (relevant to WP-3)
- Contaminant mixtures (relevant to WP-4 and -5)
- Modelling; statistics; systems ecology; alternative modelling methods (e.g. Bayesian) (relevant to WP-3, -4 and -5).
- Integration expert; development of strategic research agenda; road map development; performance indicator specialist (relevant to WP-1 and -2)
- "-omics" expert; population ecology; ecotoxicologist (relevant to WP-4 and -5)
- Education specialist; use of web-2.0; syllabus development; stakeholder participation specialist; recruitment specialist; knowledge management (relevant to WP-6 and -7).

Three members were chosen specifically outside the discipline of radioecology so that they could provide guidance on STAR activities that are beyond traditional radioecology.

Table 2*:* STAR's External Advisory Board members

EAB Member	Position / Institute	Expertise
Mikhail BALONOV	Head of Protection Lab, Institute of Radiation Hygiene, Petersburg, Russia	Radiation biology; Chernobyl Forum; ICRP member, formerly with IAEA
Maria BETTI* (left EAB in 2013 after taking a new position in the EC)	Director, IAEA Environmental Laboratories, Monaco	Radiation chemistry; radioecology; science management
Nina CEDERGREEN	Department of Basic Sciences and Environment Faculty of Life Sciences, University of Copenhagen, Denmark	Ecotoxicology; chemical mixtures; dose-response modelling; science education
Valery FORBES	Director, School of Biological Sciences, University of Nebraska, Lincoln, USA	Ecotoxicology; science education; science management; statistics
Rick JONES	Former Chairman of the OECD/NEA Committee on Radiation Protection and Public Health (CRPPH) and former head of the Radiation Control Department at the	Radiation protection; public health; science management

EAB Member	Position / Institute	Expertise
	US-DOE.	
Dick ROELOFS	Department of Animal Ecology, Vrije Universiteit, Amsterdam	Gene expression profiling and ecotoxicogenomics
Satoshi YOSHIDA	Research Center for Radiation Protection, National Institute of Radiological Sciences (NIRS), Chiba, Japan	Radioecology; science management; Asian Network of Excellence in Radioecology; IUR.

The evaluation of the STAR progress was carried out through meetings between the EAB and the STAR Management Team (initially only 3 were planned in the DoW); as well as through direct exchange by e-mails with WP leaders or participation of the EAB to specific WP meetings. Table 3 summarises the meetings where EAB members participated since the beginning of the project. All STAR deliverables were systematically sent to the EAB at the time of their release. Some of them have been sent prior to their finalisation to allow the EAB to comment prior to publication.

Table 3. Meetings attended by EAB members during the STAR project

Type	Date	Venue
EAB	7-8 June 2011	Paris, France
WP4/5	24-27 May 2011	Mol, Belgium
EAB	11-12 June 2012	Berlin, Germany
EAB	12-16 January 2014	Rovaniemi, Finland
WP4/5	1-4 April 2014	Stockholm, Sweden
EAB + Final dissemination event	9-12 June 2015	Aix-en-Provence, France

Initially, it was planned that the EAB will use the list of performance indicators provided in the DoW to evaluate the project. However, this list was not adequate from the perspective of the EAB members who preferred to evaluate the project based on the demonstration of the EC added value of our work (and not only on metrics). Therefore, the present report is composed of two sections:

- the final evaluation of STAR made by the EAB in June 2015
- the updated list of the initial performance indicators provided in the DoW

2 Final EAB report on the STAR project, June 2015

2.1 Introduction

Strategy for Allied Radioecology (STAR) is a European network of excellence funded by the European Commission under Framework Program 7 that has integrated several aspects of complex research priorities associated with radioecology for the benefit of human and environmental protection. This was achieved by collaborating in a European network of Scientific excellence. Moreover, the STAR consortium reverses the decline in interest in Radioecology through education, stakeholder participation and integration in support of the radioecological needs of industry, national authorities, and the public.

STAR kicked off in 2011 and established the External Advisory Board (EAB) to assist it in setting the right research and dissemination priorities, provide expertise in education and training courses, workshops and to evaluate the quality of the STAR consortium by assessing milestones, deliverables, accomplishments and European added value.

The STAR EAB consists of the following members, each having specific expertise regarding different aspects of Radioecology:

- Dr. Dick Roelofs (EAB Chair), VU University Amsterdam - Molecular ecology, ecological genomics
- Rick Jones, formerly with the US Department of Energy – Radiation protection
- Prof. dr. Mikhail Balonov, Institute of Radiation Hygiene - Human protection
- Prof. dr. Nina Cedergreen, University of Copenhagen - Environmental chemistry, mixture toxicity
- Prof. dr. Valery Forbes, University of Minnesota - Ecotoxicology, ecological risk assessment

The current final report provides a compilation of all information gathered by the EAB throughout the execution of STAR. It describes several aspects of what has been accomplished, which were drawn from three joint meetings of the EAB and STAR management team. Most of the input for this final report was gathered and formulated during the final dissemination event, held on June 9-12, 2015.

Overall, the EAB is very positive about the accomplishments and European added value of STAR. The EAB is certain that STAR has increased interest and awareness about radioecological issues in the European Community and beyond strengthening future scientific excellence and societal relevance on this important topic.

2.2 Summary of former EAB Meetings

2.2.1 First Meeting June 6-7, 2011

The first two-day meeting of the External Advisory Board (EAB) of the STAR Project was conducted June 2011, in Paris, France. It was an opportunity for the STAR management and team members to meet the EAB members and discuss how the EAB can best contribute to the success of the STAR Project.

The first topic of discussion, in support of the identified duties of the EAB, was to discuss the identification of Performance Indicators (PIs) for the STAR Project. After a lengthy discussion about the identification, use and purpose of PIs the EAB members provided guidance to the STAR team to go back into the Grant Agreement and look at the Objectives and Goals of the STAR Project to identify appropriate PIs for each Work Package and the project as a whole. The EAB members also provided examples of some appropriate PIs. The STAR Team agreed to work on new PIs to be provided to the EAB for review.

The EAB also noted the value of and support for the use of MBA students for the effective and efficient management of the project. The EAB commended the development of a proactive communications plan and recommended the the STAR team identify their stakeholders' information needs and proactively push or send stakeholder information of interest to them as it becomes available. The EAB also noted that the STAR Project Work Packages are aggressive, inclusive and of broad scope. The EAB recommended that the Work Package activities be prioritized and resources dedicated accordingly, with primary focus on achieving value-added results. The EAB also expressed interest to monitor the development of the transition plan to assure sustainability of the STAR Project beyond the life of the project.

The EAB also provided specific comments on each of the Work Packages. The first meeting of the EAB also resulted in matching EAB members' expertise to the STAR Work Packages and identification of an EAB member to assist each of the STAR Work Package Team Leaders.

2.2.2 Second Meeting June 11-12, 2012

The second two-day meeting of the EAB was conducted in June of 2012, in Berlin, Germany. To increase the effectiveness of the EAB it recommended that STAR management take a proactive approach regarding logistics arrangements, provide a detailed agenda for meetings, select specific issues/problems to be addressed with the EAB well in advance of the meetings so all parties could be adequately prepared, and the EAB requested the opportunity to attend meetings/symposia where STAR PhD and Post-docs present their results. Moreover, the role of the EAB with regard to the Strategic Research Agenda (SRA) and associated Road Map was very unclear. The STAR management team was asked to clarify EAB's role in the SRA.

EAB formulated the following specific recommendations per work package:

Work Package 2:

The EAB recommended the inventory of equipment be focused only on highly specialized and/or expensive equipment to make it a more manageable project. Also, the decision process needed to be identified to prioritize the selection of observatory sites in order to better focus resources more quickly.

Work Package 3:

The STAR project needs to define the program for protection of the environment and differentiate between normal operations, emergencies and recovery with a clear focus on the environmental aspects.

Work Package 4:

Hypotheses for the conduct of research were reformulated together with the EAB responsible WP leader during the meeting.

The justification for the use of molecular analysis in future STAR research was discussed extensively. The EAB responsible member, Dr. Roelofs, agreed to assist the STAR team as needed. Indeed, he conducted discussions on this topic and presented his view on the topic during an IRSN meeting later in June 2014.

The EAB requested clarification on the role of Debtox analysis in mixture toxicity experiments.

Work Package 5:

The EAB was concerned about having sufficient data to support modeling and requested clarification on proposed experiments to investigate differences in radiosensitivity. It was also recommended to apply analyses at different levels of biological organization to a single set of model organisms to be used in Work Packages 4 and 5 as this will be highly beneficial for integration and the quality of scientific output. The EAB also noted that the model species were well chosen and good progress had been made regarding the Debtox modeling with *Daphnia* and *C. elegans* data.

Work Package 6:

MSc internship rules, exchange, practicality and economic impact were not clear. Probably, more students would be attracted if a clear flyer on this was formulated and distributed. The EAB offered to assist in promoting the educational program.

Work Package 7:

The EAB offered to recommend to the EC and ALLIANCE the urgency to maintain the STAR database/gateway in the long term.

2.2.3 *Third Meeting January 14-16, 2014*

The third meeting of the STAR External Advisory Board (EAB) met in Rovaniemi, Finland on 15 January 2014. Again, issues for each STAR Work Package were discussed, and are summarized below:

Work Package 1: Communication Challenges with Stakeholders

The EAB recommended that STAR should focus its activities and resources promoting STAR contributions and accomplishments to advancing radioecology, maybe by using Fukushima as an example. The STAR Project should also promote more proactive communications in the conduct of future activities.

Work Package 2: Challenges of Integrating Consortium Partners

EAB recommended that STAR continue its initiatives within COMET in order to have access to Observatory sites. The signing of an MOU to establish the Open Project for European Radiation Research Area (OPERRA) is an opportunity the STAR project should pursue to formalize the establishment of MOUs between researchers and Virtual Site owners for the conduct of critically important on-site research The EAB further requested that STAR recommend that OPERRA conduct proactive outreach to ongoing activities to eliminate duplication of activities and prepare members, the professional community and international organizations to anticipate and use OPERRA products and deliverables.

Regarding web based communication STAR should keep track of website and database use and include a survey by visitors and users to indicate if they found the site and data bases useful or not.

Work Package 3: Integration of Human and Non-human Assessments

EAB provided comments on their latest paper concerning the integration of human and non-human radiation protection assessments. The paper needs to clarify: 1) If the biological processes are the same or different; 2) What are the end points to protect against; and 3) Identify the intended use and target audience of the final product. The STAR should demonstrate that combining human and non-human assessments will provide value added.

The EAB also provided detailed comments on the text of the paper.

Work Package 4: How should we best plan the remaining time allocated to WP4: still conduct fluoranthene exposures? and Is there still room for mixtox risk assessment?

After much discussion the EAB recommended that the fluoranthene experiments be abandoned. The project should focus on the completion of the U-Cd and gamma-Cd experiments and explain the antagonism phenomenon and its mechanisms of interaction. The project should also show the impact, or lack of impact, of mixtox risk assessments on radiation protection criteria. The remaining time and effort should be devoted to the

development of dose response curves for identified mixtox situations and not pursue risk assessment activities.

Work Package 5: Definition of a Robust Protection Criterion for Populations

The Work Package 5 team requested comment on establishing a protection criterion of 10% reduction in the lambda value for species extinction with an end point being the protection of the most sensitive individual. The EAB identified that, based upon the radiation exposure scenario, there may very well be the need to identify and use different end points. For example, in the case of "recovery" activities an end point of species growth rate is most appropriate.

The EAB proposed the use of focal species in parallel with the usual ecotox models so that extrapolation to field situations can be better addressed or quantified.

The products of the work package should clearly identify and communicate their assumptions so readers can evaluate their usefulness to given situations.

Work Package 6: The Education and Training Strategic Agenda: Ensuring Funding and Sustainability

The EAB congratulated the STAR team on their advances to expand education and training in radioecology and the success and increased interest in their MSc courses.

The EAB fully supports the inclusion of Education and Training into the Strategic Research Agenda (SRA) in order to have scientists available to conduct the research needs of the future.

Work Package 7: Suitable topics for a data workshop

The EAB recommended that STAR use well established protocols for the conduct of field activities and bring statisticians in at the planning stage of field activities to make sure sufficient data are collected to establish the statistical strength of results.

Update the EAB on STAR transition to COMET

The EAB was provided with a briefing on the sustainability of the STAR program initiatives for transition to the COMET and OPERA programs

Open issues from 12 June 2012 EAB Meeting

As stated at the 2012 meeting, the EAB would once again request the opportunity to attend meetings, symposia or workshops discussing STAR projects.

The previous EAB recommendations relative to Work Package 3 have not been effectively addressed. The STAR project was requested to take action to further develop the system of environmental protection.

The STAR program should clearly identify to the EAB if they are going to pursue the development of molecular mechanistic research as discussed in Work Package 4.

2.3 Accomplishments and European added value

Accomplishments and European added value are formulated below per work package:

2.3.1 Work Package 2 - "Integration and Infrastructure"

1. **Work Package leader:** Tarja Ikäheimonen (tarja.ikaheimonen@stuk.fi)

2. **Comprehensive list of accomplishments**:

The first Radioecology Strategic Research Agenda

Virtual laboratory

Infrastructure catalogue

Radioecological observatories

Long-term integration -> the Radioecology Alliance, COMET, CONCERT etc.

3. **European added values of the accomplishments**:

Establishing and maintaining the Strategic Research Agenda

The first Strategic Research Agenda (SRA) (D2.1, Apr12), which provides a long-term vision (15-20 years) of radioecological research needed, was created. It was also updated taking into account the comments from stakeholders and experts and by adding a new strategic part focusing on Education and Training challenges, the associated vision and key action lines.

It was originally planned that STAR would prepare the roadmap associated to this SRA. However, this task is done under the COMET project. At present, seven working groups (WGs) have been launched aiming to build a five-year roadmap. The six topical WGs are dealing with: marine radioecology, NORMs sites, forest radioecology, human food chains modelling, inter- and intra-species radiation sensitivity and transgenerational effects. A 7th topical WG is under development (atmospheric radionuclides and transfer processes).

Virtual laboratory

The Virtual Laboratory is a space within the Radioecology Exchange (www.radioecology-exchange.org) website established by STAR. The aim of the Virtual Laboratory is to provide openly available information to encourage integration through joint research and joint use of infrastructure. The Virtual Laboratory provides information on methods and procedures, facts and datasheets, radioecology models as well as lectures and videos. It will also begin to

establish the integrated use of data and sample materials within the network and by the wider community.

Infrastructure catalogue

To ensure effective collaboration and integration, an inventory of infrastructure covering equipment, methods, bioinformatic equipment and methods, sample archives, models, expertise and facilities for radioecological research was created. The list of the facilities available for others is in the public domain of the Radioecology exchange under "Virtual laboratory, Equipment and facilities. To best utilise existing resources, the emphasis is on promoting the visibility and joint use of existing infrastructures - and this is what the infrastructure catalogue does. The infrastructure catalogue is a useful tool for partners to search for skills and services the other partners have to offer.

Radioecological Observatories

One of the novel ideas for integration was the creation of Observatories for Radioecological Research. Radioecological Observatories are contaminated field sites that provide a focus for long-term joint field investigations. Three contaminated sites have been selected as the most promising options as Radioecological Observatories sites: areas near Chernobyl contamination exclusion zone (CEZ), a previous coal mining and processing site in Poland and a forest in the Fukushima prefecture in Japan, affected by the accident at the Fukushima Dai-ichi NPP (under the EC COMET project). The progress under the STAR project has not been as fast as expected:

- Following a site visit in the Polish Observatory site in August 2014 it became clear that contamination levels at the site may be too low to allow for the creation of an observatory site.
- Concerning the CEZ the next step will be to define smaller areas that are suitable to address the research lines prioritized in the SRA and the implementation plan.

Despite the difficulties, the observatory sites have enhanced collaboration between the partners, and there is still confidence in the observatory sites.

Long-term integration

Integration of the European radioecology community is underway with the help of STAR partners. The ALLIANCE, officially formed as an association in September 2012, expanded from the initial eight founding members (BfS, CIEMAT, IRSN, NERC, NRPA, SCK•CEN, SSM, STUK) to 21 members from 14 countries.

The work to promote radioecology will continue under CONCERT: The CONCERT proposal sent to H2020 EJP call in Sep 2014 was accepted. There are 52 partners in the consortium including research platforms ALLIANCE, MELODI, NERIS and EURADOS.

As pointed out above, STAR has made considerable progress in enhancing the long-term stability and sustainability of radioecology in Europe. The collaborative work and joint research strengthens radioecology and enables partners to achieve their mutual goals. The STAR partners managed to integrate even further than was imagined at the beginning of the project.

In total 2011-2015, ten milestones and six deliverables were achieved and two papers on the STAR Project were published.

2.3.2 Work Package 3 - "Integrated Human and Non-human Radiation Protection"

1. **Work Package Leader:** Astrid Liland (astrid.liland@nrpa.no)

2. **Comprehensive list of accomplishments**:

In view of furthering development of an emerging system of environmental radiation protection, the WP3 partners substantially advanced wildlife dosimetry by application of extrapolation approaches in radioecological transfer models. They organised a wildlife dosimetry workshop with international experts in 2014 that addressed a wide spectrum of wildlife dosimetry issues.

The most important output has been the development of a joint screening model for humans and biota. The CROM8 code was released for public use in April 2015 where human risk assessment and environmental risk assessment can be performed via different modules within the same tool. It is based on the earlier versions of CROM for human risk assessment, with some revisions, and the ERICA Tool for environmental risk assessment.

Several actions were undertaken in WP3 to support the development of an integrated tool:

- The use of Features, Events and Processes (FEPs) analysis together with Interaction Matrices (IMs);
- Reflection on the feasibility of integrating the human and environmental frameworks on a conceptual level;
- Feasibility of iteratively improving a model for integrated protection by mechanistically modelling key processes;
- Extrapolation techniques, and
- Wildlife dosimetry (workshop)

As part of the last action, STAR organized a wildlife dosimetry workshop with international experts in May 2014. It addressed a wide spectrum of questions related to wildlife dosimetry. World leading experts from 12 countries presented state-of-the-art scientific achievements and participated in discussions on four main topics:

- Internal dosimetry and biokinetics in wildlife

- Wildlife dosimetry fit for purpose
- Uncertainties in wildlife dosimetry
- What improvements are needed in wildlife dosimetry and why?

Fukushima research was introduced in the STAR project following an open call on this issue. Task 3.5 on fluxes and trophic transfer of radiocaesium in marine ecosystems off Fukushima has brought new insight into marine radioecology, in particular the role of sediments as a sink and secondary source of contamination of fish.

3. European added values of the accomplishments:

WHY: The human and environmental radiation protection frameworks have evolved somewhat independently and created parallel radiological protection systems over the preceding years. They diverge in many respects such as end points, sophistication of dosimetry, dose limits/consideration levels etc., but the underlying dispersion and transport processes are the same. Indeed, the dispersion of radionuclides in the environment would be the same regardless of whether the end point of the risk assessment is humans or biota or both, since the underlying physical and chemical processes are independent of the species that are exposed. A risk assessment tool that could combine human and biota calculations in the same code would give more coherence to risk assessment for a given scenario. For regulators, a combined tool would be more resource-efficient than to perform assessments for humans and biota separately with two different tools for the same site.

WHAT: The reflection on the possible integration of the radiation protection *frameworks* has highlighted the possibilities and challenges to such an approach. In short, using the same dispersion and transfer models is justified while challenges remain for e.g. protection endpoints, availability of transfer data, sophistication of dosimetry, spatial and temporal variability influencing transfer and exposure, and availability of relevant data on dose-effect relationships

IMPACT: The reflection and work on the integration issue has significantly benefited from a joint European effort. The STAR partners have different fields of expertise that contributed to a more holistic view of the topic. FEPs and IMs in particular benefit from a discussion among a larger group of various experts to ensure all relevant elements are included. Integration of modelers in human risk assessment with modelers in biota risk assessment was the key to develop the integrated codes CROM8 and CROMERICA with the associated parameter values. The latter were improved by new experimental data and extrapolation techniques from several STAR experts.

SUSTAINABILITY: The reflection on the integration of the radiation protection frameworks for humans and biota can serve as input to the larger radiation protection community in the development of new recommendations for protection. The CROMERICA development will continue after STAR ends, with cooperation between several institutes and the IAEA, led by

CIEMAT. STAR partners expect this to continue for CROMERICA, in particular because the ERICA Tool developers are now well integrated with the CROM developers thanks to STAR. Of course, the need for some future funding is clear, mainly for arranging users and developers courses or if specific development needs appear.

In total during 2012-2015, 5 deliverables achieved, 16 papers published in peer-reviewed journals.

2.3.3 Work Package 4 - "Radiation Protection in a Mixed Contaminant Context"

1. **Work Package Leader:** Hildegarde Vandenhove, hvandenh@sckcen.be

2. **Comprehensive list of accomplishments:**

WP4 – Task 1: Critical review of existing approaches, methods and tools for mixed contaminant exposure, effect and risk assessment in ecotoxicology and evaluation of usefulness for radioecology

WP4-Task 2: Testing the feasibility and applying existing approaches and tools for robust radionuclide (RN) bioavailability assessment under mixed contaminant conditions

1. Establish whether co-contaminants have significant impact on the speciation and thus the availability of the radionuclides. Geochemical modelling of four U and Th-impacted waters was carried out using different geochemical speciation models. No general effect of co-contaminants on uranyl or thorium speciation was found, with the exception of a small effect of the presence of iron(III) colloids on uranyl speciation in slightly acidic water.

2. Development of a Uranium BLM for aquatic organisms under mixed contaminant conditions
   - Model developed for salmon (*Salmo salar*) (NMBU), *Daphnia magna* (IRSN) and *Lemna minor* (SCK•CEN, STUK and BfS). For *D. magna* significant effects of pH, Na, Mg and Ca on uranyl toxicity have been found. For *L. minor*, effects of Mg, Ca and pH on accumulation and toxicity can be seen.
   - A spread sheet tool has been developed to address fitting of BLM parameters to the data.
   - A two-site Biotic Ligand Model (BLM) for accumulation and toxicity was developed for *S. salar*, based on trends in the sublethal accumulation of U on the gills and on mortality.
   - A two-site BLM for accumulation and toxicity was developed for *L. minor*, based on trends in tissue accumulation and on growth inhibition.

- A single site BLM, with multiple binding species, was developed for *D. magna* based on mortality.
- Generally, trends in uranium toxicity and their relationship to uranium chemistry are more complex than are typically seen for non-radionuclide metals

WP4-Task 3: Apply selected approaches developed in ecotoxicology to assess the impact of mixed contaminant conditions on radiation induced effects and improve the understanding of underlying mechanisms and processes

1. Binary mixture exposure experiments applying classical ecotoxicological settings and CA/IA.
   - Developed for external gamma irradiation + Cd and U(VI) + Cd; some combined exposure experiments were also performed with fluoranthene.
   - Experiments set up with *C. elegans* (IRSN), L. minor (SCK•CEN), *Salmo salar* (NMBU), phyto- and zooplankton (SU).
   - Based on initial datasets and analysis more targeted experimental designs have been established that better take into account the limitations imposed especially around the logistics of the radiation source exposure facilities and effects.
   - However, STAR results did not answer all the issues in support of the development of an ERA.
2. Development of a Mix-DEBtox for *C.elegans* and *L. minor*.
   - For *C. elegans*
   - The data on U and Cd obtained from CA/IA experiments were used to explore the underlying mechanism of interaction with the support of DEBtox modelling.
   - Simulations have successfully described the toxicity of U and Cd alone, consistent with previous DEBtox modelling for U and Cd.
   - To describe the combined effects of U and Cd, an interaction term was considered in the various physiological parameters of the model.
   - For *Lemna minor*, no Mix-DEBtox model will be developed: the development of a DEB and DEB-tox model took longer than expected.

3. European added value of the accomplishments:

INTEGRATION

- Increased integration of the research groups in Europe dealing with research in multiple stressors (MS) in an ionising radiation context. Increased integration of experimentalists and modellers.

  → important since MS experiments are very demanding and require a multidisciplinary approach and shared infrastructure (chemistry, (molecular)biology, geochemical

modelling, effects assessment models, irradiation facilities and facilities to work with radioactivity, …).

TOOLS AND DATABASE DEVELOPMENT

- Good experimental and modelling practice developed (experimental and modelling tool box) which will be communicated to the broader public via the Radioecology exchange.

  STAR has established an important dataset of new high-quality data which are available for others for additional analysis upon request.

  → will allow for future more robust predictions/conclusions and/or such larger dataset will help in evaluating/demonstrating the robustness of research findings.

SCIENTIFIC ADVANCES

- STAR research has demonstrated that co-contaminant effects on mobility of uranyl and thorium series radionuclides in water appear to be minor.

  → implies that further research can better concentrate on how the other contaminants affect bio-availability and toxicokinetic/toxicodynamics of radionuclides.

- The science done in STAR is close to the forefront of efforts to explain mixture toxicity using BLMs. STAR not only studied such effects but also quantified them for predictive purposes in BLMs. Following on from the development of BLMs for single species, the mix-BLM models allowed for interpreting the observed U/Cd mixture effects in terms of competitive uptake of the toxicants.

  → demonstrates the importance of obtaining information about speciation in exposure media as well bioaccumulation, when linking exposure to effects.

- Studies done under STAR represent the majority of the existing studies of uranium and radiation ecotoxicology in the species used.

- STAR showed that processes interacting at different levels may result in deviation of mixture effects from the reference model (CA, IA) predictions.

ADVANCES FOR RISK ASSESSMENT

- For the scenarios tested and based on the presently available data, STAR demonstrated that effects observed could be predicted using CA/IA or deviations thereof.

- STAR results also demonstrated interactive effects. Although STAR research found mostly antagonism, some synergistic interactions were however also found (e.g. in *Lemna* and salmon).

VISIBILITY

- The high (expected) publication record of STAR will increase the visibility of the EC supporting these activities and will trigger further research in this area as STAR could only begin to explore this field.

In total 2011-2015, eleven milestones and four deliverables were achieved and eight papers on the STAR Project were published.

2.3.4 Work Package 5 - "Ecologically Relevant Low Dose Effects

1. **Work Package Leader:** Frédéric Alonzo (frederic.alonzo@irsn.fr)

2. **Comprehensive list of accomplishments:**

Conducted alpha and gamma radiation experiments, using a common experimental plan:

- nematodes studied at SCK•CEN with IRSN collaborators and at IRSN with NMBU collaborators;
- parallel Zebrafish studies at IRSN and UMB;
- studies in plants at SCK•CEN, in daphnids at IRSN and salmons at NMBU.

Acquired new experimental data on survival, growth and reproduction effects over full life cycles during chronic multigenerational exposure to gamma and alpha radiation in animal and plant species:

- in the duckweed *Lemna minor*;
- in the crustacean *Daphnia magna*;
- in the nematode *Caenorhabditis elegans*.

Acquired new experimental data on molecular and cellular responses to chronic radiation:

- in *Arabidopsis thaliana* and the zebrafish *Danio rerio*;
- in *D. magna* and *C. elegans*.

Successful application of the DEBtox approach:

- to analyze gamma radiation effects in *C. elegans*;
- to explain transgenerational changes in depleted uranium effects in *Daphnia*;
- to compare gamma and alpha radiation effects in *Daphnia*.

Successful application of a classic population modelling approach (Leslie matrices):

- to extrapolate radiation effects measured in laboratory organisms to population-level endpoints and calculate population risks in 12 species representing 4 taxonomic groups (including aquatic and soil invertebrates, fish and mammals) ;
- to test population risk for a fish group, by exploring the diversity in population responses among 21 fish life cycles.

3. European added values of the accomplishments:

STAR WP5 demonstrated the capacity of radioecotoxicology for integrating (scientific objectives, approaches etc.) not only among European radioecologists, but also with the wider international ecotoxicology community studying environmental fate and ecotoxicity of chemicals.

STAR WP5 brought new knowledge for the robustness of ecological risk assessment of ionizing radiation, while the current EC approach is limited by the lack of data on chronic radiation effects, in amount and relevance, in terms of:

- range of addressed endpoints in each species;
- range of tested species to cover biodiversity;
- range of tested life stages, where full life cycles should be tested;
- exposure of a single generation, where multigenerational exposure is more relevant;
- exposure to external gamma only, where comparisons among radiation types are needed (gamma, alpha…etc.).

STAR WP5 concomitantly measured toxic effects at various levels of biological organization (molecular, cellular, histological, physiological, organism), bringing valuable data to understand mechanisms of (chemical and radiological) toxicity and to test biomarkers' relevance for both ecotoxicology and radioecology.

Novel developments in DEBtox modelling for both ecotoxicology and radioecology:

- in *C. elegans* and *Daphnia*, first applications to the case of ionizing radiation, involving a new dose metric (dose rate as an internal concentration);
- in *Daphnia*, use of a transgenerational damage compartment to mechanistically explain changes in effects across generations and link molecular alterations to effect intensity;
- in *Lemna*, contribution to the ongoing development of a DEB model for plants.

A significant methodological progress for the field of radioecotoxicology:

- Test of theoretical population risk levels in 12 laboratory species at the international reference benchmarks;
- population modelling for radioprotection purpose at an initial step with much room for future improvements.

In total during 2012-2015, 5 deliverables achieved, 4 papers published in peer-reviewed journals.

2.3.5 Work Package 6 - "Mobility, Training and Education"

1. **Work Package Leaders:** Lindis Skipperud (Lindis.Skipperud@nmbu.no) /Deborah H. Oughton (Deborah.oughton@nmbu.no)

2. Comprehensive list of accomplishments:

Work package partners have successfully increased the visibility of and student participation in radiobiology training and education. The program also enhanced student mobility as well as the mobility of STAR experts to teach the courses. The engagement of stakeholders in two workshops, to identify the demand and supply needs for training and education in radiobiology, helped to shape the program and elevate the project's visibility to create buy-in and interest in the program.

The STAR program successfully conducted eight STAR E&T Courses from PhD and MSc levels to web-based training and refresher courses. Student participation was more than a 100% increase on past attendance, with good student feedback. Increased mobility of both students participating and STAR experts teaching in the STAR courses was also realized. The program also attracted students from outside the STAR network and collaboration with other organizations (COMET) allowed for the conduct of refresher courses at the ICRER conference in 2014. The fact that the program also attracted co-funding from DoReMi to sponsor participation of additional students is further testament to the strong links and support for the program in the radiobiology community.

Action was also taken by the program to assure its sustainability once the STAR program grant has been completed. Radioecology E&T has been included in the Strategic Research Agenda (SRA) and STAR members have participated in MELODI/OPERRA E&T network meetings to initiate integration of the STAR E&T advances into OPERRA and Horizon 2020 CONCERT.

3. European added value of the accomplishments:

Overall Work package 6 has made an important contribution to the education and recruitment of students to radioecology in Europe, as well as strengthening international recognition of the importance of radioecology as a relevant discipline for other areas of nuclear science. The significant increase in the number of students taking courses and participating in the Radioecology MSc was one of the main performance indicators for the project and this indicator has been met. Participation of STAR partners as lecturers on E&T courses as well as students from different STAR partner institutions was one of the underlying aims for mobility, and has also been achieved. Written examination of students at their home universities in Europe was also successfully tested. The refresher courses were also most

useful as a relatively high number of students and researches attended the refresher courses given during the ICRER meeting at Barcelona in 2014.

The STAR Work package has also retained a high international profile by interacting with other EU E&T networks (DoReMi, CINCH, EUTRAP, NERIS, etc) that will be essential for ensuring the integration of STAR and Radioecology in future EU projects (e.g., COMET), networks and is especially important within the CONCERT JEP. This is also fundamental for the future sustainability of Radioecology E&T.

Stakeholders representing industry, authorities and academia have provided input to and supported the E&T platform. The possibilities of creating Joint MSc degrees in Europe has also been positively discussed among academic stakeholders, and will be continued within COMET.

In total 2011-2015, four deliverables were achieved and at least two papers on STAR E&T work will be finalized and published after the completion of the STAR project.

2.3.6 Work Package WP7 -"Knowledge and Data Dissemination"

1. **Work Package Leader:** Brenda Howard; (bjho@ceh.ac.uk)

2. **Comprehensive list of accomplishments:**

The achievements of this Work package have dramatically increased the visibility, scientific value and promotion of radioecology through activities in five broad areas:

Web sites: The project established the webportal Radiological Exchange as the gateway to access STAR outputs and a spectrum radioecological resources. A radioecology news and careers blog was also created and added to the STAR homepage and Exchange websites. Facebook and Twitter accounts were established as well as NoE management and STAR members infrastructure wiki's. Video's were also produced to explain what radioecology is and were posted on the Exchange. The Exchange is also to be maintained in the future via COMET and ALLIANCE.

Access to radioecological information: A Virtual Laboratory was created and added to the Exchange to enable easy access to STAR methods, procedures, protocols and data. Also created were 20 Radioecology Factsheets as well as posting information related to Fukushima research. The project also created the Information Exchange to provide access to STAR and COMET partner publications, data catalogue, newsletters, FAQ's and links to other relevant radioecology websites. Action was taken to make STAR deliverables available through Researchgate to further the visibility and contribution of STAR to radioecology.

Data: Pioneered mechanisms to improve data transparency, such as defining, developing and populating the Data Catalogue to provide access to radioecology data currently held by STAR partners.

Training and education: Designed and created the Training and Education platform and posted it on the Exchange to enhance availability and interest in STAR developed training and education initiatives.

STAR dissemination: Participated in or conducted five international or regional conferences to promote the STAR project goals and achievements.

3. European added value of the accomplishments:

With the STAR development of the Radioecology Exchange, as the gateway to accessing on-line radioecological resources, Europe now has a single website giving freely available and good quality information on environmental radioactivity and the profession of radioecology. Interest in the Exchange is growing and it is now getting around 100 unique visits per day. Discussions are underway for COMET and the ALLIANCE to continue the Exchange beyond STAR.

In support of European Commission INSPIRE directive the STAR has also made their research protocols and data available to increase transparency and support future radioecology research in Europe. The approaches developed within STAR are leading the community at the international level via the interaction with IAEA MODARIA programme where STAR partners chair four of the working groups.

For the first time the STAR project has created an active social media site for radioecology. The Exchange is a frequently updated blog and STAR has also created Twitter and Facebook accounts. These activities are enhancing radioecology in Europe and beyond as the Exchange is getting requests to post advertisements, job opportunities and meetings/conferences in and of interest to radioecologists. Other European and International organizations are now following and participating, which further establishes Europe as an important partner in advancing radioecology.

In total 2011-2015, three deliverables were achieved and two papers on the STAR Project were published.

For more information on the Accomplishments and European added value of each of the Work Packages see the annex 1.

2.4 Opportunities

The European Commission demonstrated foresight in funding the STAR program to advance radioecology in Europe. It was also fortuitous that the STAR project would be launched prior to the Fukushima accident that has once again demonstrated the importance of having robust national and international programs in radioecology to make informed and scientifically sound decisions for the protection of the environment and humans.

As noted in the previous section of this report the accomplishments of the STAR program have been impressive. In order to capitalize on the European investment, in both funding and personnel resources, in radioecology the STAR External Advisory Board (EAB) highly recommends that the activities below be pursued. As radioecology is not a priority area for research nationally or globally, Europe is in an excellent position to build upon the momentum and synergies created by the STAR project to advance radioecology and position Europe as a global leader in radioecology.

Integration and Infrastructure

The work to promote radioecology will continue under CONCERT. The opportunity with regard to radioecological research within this consortium will be to promote and administer joint programming and open research calls in the field of radiation protection research for Europe. Activities of the CONCERT consortium will focus on development of an integrated landscape for radiation protection research in Europe, but it is very important to keep radioecology on this research agenda. Only in this way will integrated research projects with state-of-the-art science be tailored to meet the radiation protection needs of society, authorities and stakeholders. Integration of education and training in the research agenda as well as optimal use of research infrastructures in Europe and beyond are essential for the success of the consortium. The challenge will be to keep radioecology a priority.

The Strategic Research Agenda (SRA) will continue to be a valuable for both the radioecology research groups as well as stakeholders to formalize priorities for radiation protection research. The existence of the SRA will prevent fragmentation and non-optimal use of resources within radioecological research. Also, the SRA will be instrumental for inclusion of radioecological research within CONCERT.

Integrated Human and Non-human Radiation Protection

To exploit the good work and accomplishments of the STAR project it is important to further develop the radiation protection system for biota/wildlife (BRP), with due consideration of the current international system of human radiation protection (HRP) (basic concepts, assessment tools and means for implementation in different exposure situations) to create a more holistic radiation protection program. In this regard it will be important to further develop the tools created by STAR that can be incorporated in BRP, and to identify missing tools that might be developed in further work in and be implemented by an emerging BRP system. The screening tool, CROMERICA, shows great promise as a code to combine human and biota assessments and is deserving of ongoing support.

The BPR system has particular significance in the remediation following the Fukushima accident and in emergency preparedness in Europe and globally. A challenging task for further development of BRP is the explicit consideration of practical means of implementation of remedial actions for wildlife protection depending on the exposure situation. Another important conceptual issue for consideration in the light of the above is consideration of the consequences of possible remedial actions for wildlife versus human

protection (depending on the exposure situation). The EAB recommends continued European support to build upon the accomplishments of STAR to create a BRP system, including tools such as COMERICA that is fully integrated with and complementary to the international HRP.

Radiation Protection in a Mixed Contamination Context

Substantial progress was made in the fundamental understanding of radiation effects in mixed environments. A major opportunity will be to integrate that knowledge into risk assessment models to more realistically model and predict effects in a multi-contamination context. The development and validation of a Biological Ligand Model (BLM) for uranium under mixed contamination context within STAR was a major achievement, which will set the stage for more optimal ecological risk assessment of radiological effects.

Another opportunity will be to publish the high quality fundamental research data obtained within STAR in higher impact journals with a broader ecological context. In that way a broader scientific community can be reached, which will be highly beneficial for the visibility of radioecological research within Europe, but also more globally.

Ecologically Relevant Low Dose Effects

The STAR project used mostly high doses of radiation in order to elicit adverse radiobiological effects in plants and animals. The opportunity exists, using the research protocols developed by STAR, to now conduct additional research to extend the range of doses and radionuclide concentrations towards the low dose area as much as possible taking into account the technical feasibility to detect radiobiological effects.

There is also the opportunity to expand the radioecological modeling products created by STAR considering the possibilities to include major radiobiological processes (cell killing and genome mutations) with their specific dose-effect dependencies as part of modeling in a wide range of radiation doses. Linking radioecological modeling to existing experimental data, for example the data collected in the ERICA database, would also enhance radioecological modeling. Some of these data could be used to derive model parameters and some of the data could be used for model validation. The EAB recommends continued European support into the ecological relevance of low dose effects from radioactivity in the environment.

Mobility, Training and Education

The STAR Mobility, Education and Training (E&T) program has made a significant contribution to help address the identified shortage of academic programs in radioecology and the number of radioecologists in Europe. As the shortage has been created over many years, so the solution will take many years to establish a sustainable level. The STAR program has demonstrated the ability to attract students, when radioecology courses and training are available. Continued European investment and support in radioecology E&T will be essential to provide a sustainable level of much needed radioecology expertise to create the basis for scientifically sound decisions. The EAB recommends continued European support for

radioecology education and training that will provide the necessary expertise for the proper understanding and management of radioactivity in the environment.

Knowledge and Data Dissemination

The Radioecology Exchange web site, and associated links, is a valuable asset for the radioecology profession and Europe as a whole. Its continuation is important in establishing Europe as a major contributor to the science of radioactivity in the environment. Understanding the impact of radioactivity in the environment continues to be important as a result of the Chernobyl accident and has become only more important after the Fukushima Accident. COMET has agreed to improve the Exchange and ALLIANCE has agreed to use the Exchange rather than create a new website. To enhance the usefulness of the Exchange and its associated links, future radioecology researchers should be encouraged to post their data on the Exchange. The Exchange also offers the opportunity to be expanded to reach out to regulators, industry and the scientific community to identify and respond to radioecology issues needing to be addressed (e.g., benchmarks, chronic exposures, the relevance of effects data, multiple stressor research). The quality and usefulness of the Exchange will be in direct proportion to the amount of funding and resources available to keep the Exchange current and its use promoted. The radioecology profession, Europe and the International community will benefit greatly in developing informed decisions concerning siting, remediation, resettlement, decommissioning and a host of other critical decisions by providing financial support and resources to the maintenance of the Exchange. The EAB recommends continued support for the Radioecology Exchange, its associated links and social media initiatives created by the STAR project.

European Commission

The STAR External Advisory Board (EAB) also identified areas where the European Commission (EC) has opportunities to enhance the effectiveness of their Grants program.

Roles and Responsibilities of the EAB: The EAB could be of greater value to the EC and be of greater assistance the Grantees if the EC were to publish formal guidance on the roles, responsibilities and EC expectations for an EAB. It would be important to identify, for example, if the EC expects the EAB to be more of an oversight group or if they are to partner with the Grantee to advance the project. It would also be important to identify the responsibilities of the Grantee to respond to and take action in response to EAB recommendations and comments.

Performance Indicators: The EC is moving from tracking metrics (e.g., Deliverable, Milestones and number of published papers) to monitoring performance indicators. The use of performance indicators is a new approach and concept for Grantees and the use of performance indicators, instead of metrics, has not been incentivized. It would benefit the EC and Grantees for the EC to publish formal guidance on Performance Indicators and incentivize their use by Grantees.

Horizon 2020/CONCERT: In order to bring the best and brightest researchers with new and state-of-the-art ideas to address long-standing issues in radiation protection (e.g., low dose effects, the shape of the dose response curse, radioecology) the EC should take the opportunity to ensure that the Calls for Proposals under the new CONCERT program are transparent and completely open. The selection process for issuing Grants should also include support and funding for research across all the various disciplines within the radiation protection profession (e.g., medicine, radiobiology, radioecology, etc.).

3 Review of the performance indicators

In STAR DoW, a list of Performance indicators (PIs) characterizing the quality and success of the project was proposed. Five categories were considered for the evaluation of the project success: Research, Dissemination, Education, Management and Integration. In each category, PI's were defined to assess specific success factors.

3.1 Research

3.1.1 Relevance of research

Two PIs were proposed to evaluate the relevance of research:

- PI-1. Research is focused on key issues identified by the ALLIANCE Strategic Research Agenda (SRA)
- PI-2. Research results are published in well-respected, peer-reviewed journals

STAR's three research lines are: (1) to integrate human and non-human radiation protection approaches; (2) to determine if radiation protection criteria for humans and wildlife need to be considered within a mixed contaminant context; and (3) to enhance the scientific robustness of ecological protection criteria and their applicability as protection benchmarks. The research lines are relevant from the perspective that each was identified as an important topic within the Strategic Research Agenda (SRA) of the ALLIANCE which has identified 3 challenges relative to exposure analysis (challenge 1), effects analysis (challenge 2) and risk characterization, along with risk management and communication (challenge 3) associated to 15 Research lines.

Work within the STAR consortium has resulted in 32 publications to date (see list in annex 2), in peer-reviewed journals. More publications are expected since the promotion of all the work done in STAR continues.

Work done in STAR has also been promoted though presentations (oral or posters) given in a number of international scientific conferences, including:

- The Norwegian Society for Radiation Protection Conference, Reykjavík, 22-25 August 2011.

- The 2nd International Radioecology Conference (ICRER), Hamilton 2011, where STAR was given a 1.5 hour time slot in a special session on "the integration of international radioecological efforts" (23 June 2011).
- The 12th International Conference of the Biogeochemistry of Trace Elements (ICOBTE) conference, Athens, Georgia, USA; 2013 where STAR co-chaired the special symposium on "Environmental Radioactivity: Legacy Sites, Chernobyl and Fukushima" (with associated special issue of J. Environmental Radioactivity, vol. 131).
- The Society of environmental Toxicology and Chemistry (SETAC) conferences (SETAC North America 35th Annual Meeting, Vancouver 2014, SETAC Europe 34th Annual Meeting, Basel 2014 and SETAC Europe 35th Annual Meeting, Barcelona 2015) where research done under WP4 and WP5 were promoted through posters and oral presentations.
- The 4th Dynamic Energy Budget Symposium, Marseille 2015, where STAR research was promoted through oral presentations.
- The 3rd International Radioecology Conference (ICRER) in Barcelona, 2014, where STAR gave refresher training courses and promoted its research through posters and oral presentations (15 presentations)

3.1.2 Exploitation of results by end-users

Four PIs were proposed to evaluate the relevance of the exploitation of results by end-users:

- PI-3. Open inter-disciplinary workshops
- PI-4. International collaboration
- PI-5. Number of attendees to workshops
- PI-6. Collaboration with EU- and international projects

STAR held 9 open inter-disciplinary workshops for whose resources were allocated to attract specified individuals that hold important data sets, as well as relevant expertise. The workshops attracted many relevant members of the research community. Information on the workshops is available at: https://wiki.ceh.ac.uk/x/u4XXD. One workshop was under WP3, two under WP4, one under WP5, one common to WP4 and WP5 and four under WP7/2:

- International workshop on wildlife dosimetry (WP3) in June 2014, Madrid; https://wiki.ceh.ac.uk/x/14HHD and D3.2). The workshop addressed a wide spectrum of questions related to the ionising radiation dose estimation in animals and plants, counting with world leading experts in each of the issues discussed. There were 30 participants from 12 countries (Belgium, Canada, France, Japan, Norway, Portugal, Russia, Spain, Sweden, United Kingdom and the USA).
- Workshop on the state of the art of multiple stressor research, including a session on the Dynamic Energy Budget (DEB) theory held in May 2011, Mol (common WP4-WP5; related to MS4.1 and MS5.3 respectively).
- Expert consultation workshop to establish the final research and experimental programme of WP4 held in January 2012, Brussel (MS4.3).

- Workshop on Mixture Toxicity at SCK•CEN in Mol, in January 2014 (WP4).
- Workshop on transgenerational and epigenetic mechanisms of radiation toxicity at chronic doses (related to MS5.11) as a joint activity between STAR WP5 and COMET in December 2014, Oxford. The workshop addressed a wide spectrum of questions related to long-term and transgenerational exposure, in laboratory studies of radiation and chemical effects, molecular biology relating to epigenetic mechanisms, human and ecological risk assessment and radiological protection. World leading experts in each of the subjects attended the workshop. In total, there were 48 participants from 12 countries (Belgium, Canada, USA, Spain, France, Germany, Japan, Norway, Portugal, United Kingdom, Russia and Sweden). Outputs are available from: https://wiki.ceh.ac.uk/x/u4XXD
- Two "Kd" workshops, in collaboration with IAEA MODARIA WG4 (WP7). The first Kd workshop was held in May 2014 in Oslo and the second in Monaco in April 2015. Outputs are available from: https://wiki.ceh.ac.uk/x/u4XXD.
- The workshop on data availability, in April 2015, Vienna (WP7), in collaboration with working groups 4 and 8 of the IAEA MODARIA (http://www-ns.iaea.org/projects/modaria/default.asp?l=116). The meeting was attended by 32 scientists from 11 countries and the IAEA; the majority of attendees were not involved in the STAR NoE. Outputs are accessible from: https://wiki.ceh.ac.uk/x/u4XXD.
- The STAR final dissemination event, in June 2015, Aix-en-Provence where STAR scientific results were presented to a wide audience, with more than 100 attendees with roughly half being out with the STAR consortium.

Representatives from industry or regulatory bodies participated in most of these workshops. All these workshops are detailed in D7.2 "Dissemination Plan" released in July 2015.

Consultations with stakeholders were vital to the development of the STAR Strategic Research Agenda. Stakeholders also provided advice and input in to STAR deliverables (e.g. D4.1). They also contributed to the lively debate sessions at the STAR dissemination event held in Aix-en-Provence in June 2015. Stakeholder consultation relative to the SRA includes the:

- web-consultation in 2012 (via the Radioecology Exchange) to collect comments on the Strategic Research Agenda. An invitation to comment on the SRA and to participation in developing the next version was sent via email to some 3000 individuals worldwide (from ~85 countries). 110 comments from organizations of 36 countries (regulators, industry, research, consultants, NGO) were obtained via a questionnaire available on the STAR website.
- Stakeholder's Workshop on the first STAR Strategic Research Agenda for Radioecology, held in Paris, November 2012. The workshop was attended by 85 attendees from 17 countries, with roughly half being outwith the STAR consortium.
- consultation and debate sessions at the STAR final dissemination event.

Regarding international collaborations, STAR has built strong collaborations with several international organisations:

- *Collaboration with IAEA*

An active relationship emerged between STAR and IAEA during the project. Indeed, STAR partners are key contributors to the ongoing IAEA activity of updating the 'SRS 19' report (IAEA 2001). Contributions include updating the existing human assessment methodology and creating the methodology to be used for non-human biota. The IAEA have agreed that the approaches developed can be incorporated into the CROMERICA model (see section 2.2.2) though the new methods used for non-human biota first need to be prepared as a refereed paper (NRPA and NERC-CEH leading).

MODARIA activities on modelling of radiation effects in wildlife species greatly benefited from STAR methodological developments on modelling of population responses to ionizing radiation (see D5.2 *"Life history traits, radiosensitivity and population modelling: methods to extrapolate from individual endpoints to population dynamics"*) and calculation of ecological risk to populations (see D5.5 *"Protection criteria: Integrating radiation effects from molecules to populations and evaluation of group-specific criteria"*). Several STAR partners participated to the development of the database on life history, ecology parameters and radiation effects for wildlife animal and plant species produced by IAEA MODARIA Working Group 9. This work will lead to the publication of an IAEA report and several articles as part of MODARIA WG9 (IRSN leading) and a data paper to be prepared (NERC-CEH leading).

STAR partners were also key contributors to the development of the database on wildlife biological half-life values produced by IAEA MODARIA Working Group 8. During its development the database was used to blind test models developed by STAR WP3.

In addition, STAR has conducted three workshops in collaboration with the IAEA MODARIA WG4 on 'making data available' and efforts to establish an improved partition coefficient (Kd) database (see section 2.2.6).

- *Collaboration with ICRP*

Other co-operation is between STAR and ICRP. From the beginning of the project, STAR has communicated its results to ICRP effectively since three individuals from STAR partners (IRSN, CIEMAT, SCK•CEN) are also members of ICRP Committee 5 dedicated to protection of the environment. During the two last annual Committee 5 meeting (Abu Dhabi, 2013 and Barcelona, 2014), European project outcomes were presented and discussed under the item "International and national outcomes". The next annual C5 meeting will take place in Seoul (October 2015), jointly to the ICRP international symposium, and a time slot will be requested to the C5 chair to share the key messages from the STAR final dissemination event held in Aix en Provence (2015). Outputs from STAR may surely influence the priority list of PhD topics suggested by ICRP. Additionally, outcomes from STAR WP3 and WP5 will help the development of the work planned by Task Group 99 dedicated to "RAPs monographs", mainly by using inference methods developed under STAR either for quantifying radionuclide transfer to species or for treating the individual to population extrapolation issue. An ICRP

Task Group will utilise outputs of the STAR WP3 extrapolation task. Finally, the ALLIANCE has just sent an expression of interest to the ICRP scientific secretary, to become a liaison organisation to ICRP.

- *Other collaborations*

STAR established relationships with many other stakeholders, including representatives from industry and regulatory bodies, as well as other international organisations such as IUR, OECD-NEA, UNSCEAR, etc. or other network of radioecology, such as NCORE. These stakeholders were consulted by STAR during all the project lifespan (for the Strategic Research Agenda, for workshops on E&T, etc…), as well as at the STAR final dissemination event.

- *Collaboration with EU- and international projects*

In the framework of building a European area for radiation protection, STAR and the ALLIANCE developed strong collaboration with the other radiation protection platforms (MELODI, NERIS, EURADOS) as well as with some EU-project such as DoReMi. Representants of the platforms were invited at all stakeholders, dissemination meetings hold by STAR. The outcomes of these collaborations are obvious through the participation of all STAR partners to the EU COMET ("COordination and iMplementation of a pan-European instrumenT for radioecology") project started in June 2013, and the participation of the ALLIANCE in the CONCERT project (funded by H2020 and started in June 2015).

3.1.3 Observatory for Radioecological Research

Three PIs were proposed to evaluate the relevance of observatory for radioecological research:

- PI-7. Establishment of sites
- PI-8. Communication of their potential to the wider scientific audience
- PI-9. Number of participants outside of STAR

STAR established a list of candidate for the Observatory sites, including a coal mining site in Poland, Chernobyl, a French uranium mining site near Clermont-Ferrand, a German site in a former uranium mining area and Fukushima. The sites were discussed with input from invited experts outside of the STAR consortium at a workshop held in Berlin, 13-14 June 2012. Meanwhile, STAR developed a list of selection criteria for the evaluation of potential Observatories for Radioecological Research. Based on this list and the Observatory workshop in Berlin (June 2012), two sites were finally selected: a coal mining site in Poland that contains radium contaminated settling ponds and the Chernobyl exclusion zone. The Fukushima area was further selected as an additional Observatory site in the COMET project.

Basic information on the selected Radioecological Observatory sites is accessible on the Radioecology Exchange website (see: https://wiki.ceh.ac.uk/display/radex/Observatories).

Links provide overviews of the Observatory sites in the Chernobyl Exclusion Zone (see: https://wiki.ceh.ac.uk/display/radex/Chernobyl+Exclusion+Zone) and the Upper Silesian Coal Basin (see: https://wiki.ceh.ac.uk/display/radex/Upper+Silesian+Coal+Basin). All information on the Polish Observatory sites that was available from scientific literature or other publications, including Polish grey literature, is compiled in a comprehensive document. This document will be made available shortly on the Radioecology Exchange website. This website is intended to be the repository that provides easy access to data and information.

However these two sites are actually used by some STAR partners in the framework of non-STAR projects:

- NERC-CEH and IRSN led some research activities at the CEZ (e.g. TREE project)
- IRSN led some research activities at the Polish Observatory, through a bilateral collaboration with GIG

Within COMET, the concept of Radioecological Observatories will be further developed, including mechanisms to access these sites for hypothesis-based field investigations. In the long term, the ALLIANCE will ensure that establishing Radioecological Observatories will be a successful initiative and broaden the range of Observatory sites.

The Observatory concept was frequently presented and promoted at the STAR workshops (SRA workshop in November 2012, Final dissemination event in June 2015) and at international conferences (2nd ICRER in 2011 and 3rd ICRER meeting in 2014).

3.2 Dissemination

3.2.1 Wide dissemination of high-quality results

Three PIs were proposed to evaluate the relevance of the wide dissemination of results:

- PI-10. # of original publications
- PI-11. # of visits to public web site
- PI-12. # of press releases

STAR produced 32 original publications (see annex 2). Information on publications from the STAR project is available on the STAR project website here: https://wiki.ceh.ac.uk/x/a4FiC (with hyperlinks to the documents where possible).

Besides, STAR produced 36 reports as STAR deliverables. All of them are public, or will be public after a certain period of time (an embargo of 2 years has been put on some of them to wait for the publications of the results) and most of them are available through the Radioecology Exchange website (only WP1 relative deliverables are not on the website). Recently most deliverables have been made available through Researchgate which has greatly enhanced their availability and visibility. They are currently being downloaded frequently by followers.

STAR has restructured the initial project website beginning in spring 2014. STAR and COMET were provided with 'project' websites (www.star-radioecology.org and www.comet-radioecology.org) containing: project descriptions, deliverable reports and a news blog. All

other information, such as the 'virtual laboratory' and the 'training and education platform' (both developed by STAR and enhanced by COMET) are located on www.radioecology-exchange.org, which is now a 'hub' website for information related to radioecology. Currently, the Radioecology Exchange website has commonly 100 unique visits per day. We firmly believe this will increase further given the enhanced effort to improve the site prior to the dissemination event and the end of the project.

Regarding the press release, the STAR project was highlighted at the beginning of the project in the EC parliament magazine (issue 332; 18 July 2011). No other press release was done after, since STAR focused on other way of disseminating results (news blog and social media, for example; see D 7.2 *"Communication Plan"* for further details).

3.2.2 Data management

One PI was proposed to evaluate the relevance of data management:

- PI-13 Effective use of internet in establishing public accessible data bases

Some STAR Partners agreed to use the NERC-CEH Information Gateway to provide access to radioecological data which is compliant with the European INSPIRE Directive. Metadata and, in some instances, data can be accessed using the search term STAR NoE. Metadata describing the data were indexed to aid 'searchability' and was made publically available via the Radioecology Exchange.

To provide mechanisms to improve data transparency work package 7:

- designed and set up a STAR members data holdings wiki; see: https://wiki.ceh.ac.uk/x/EwGsC (log in needed) - the information collated using this wiki was used to populate the data catalogue (see below).
- defined, developed and populated the data catalogue to provide access to radioecology data held by partners (D7.3) see: https://wiki.ceh.ac.uk/x/DYFsD.
- will provide access (via the data catalogue) to data produced during STAR on the Radioecology Exchange after it is published in the scientific literature (related to D7.3; due July 2015).

EURATOM publications collated by STAR have also been made available for IAEAs International Nuclear Information System (INIS) (see http://www.iaea.org/inis/).

Data-related activities are summarised in D7.3 released in July 2015.

3.3 Education

3.3.1 Educating young scientists

Four PIs were proposed to evaluate the relevance of educating young scientists:

- PI-14. # of education and training courses;
- PI-15. # of MSc and PhD theses;

- PI-16. # of students entering and passing
- PI-17. feedback from students

STAR has developed the Radioecology Education and Training Platform (E&T platform). It is a website focal point for students and professionals interested in radioecology. The platform presents an overview of education and training course modules within radioecology/environmental radioactivity presently offered by the STAR consortium. Information on course curriculums and learning outcomes are provided, with recommended pathways to obtained academic merited education (MSc, PhD). The Radioecology E&T platform also provides links to other E&T platforms, such as those within Radiochemistry, Radiobiology and Radiation Protection. This is an important outreach mechanism for the Radioecology E&T platform, as – for example – many of the basic course modules within radioecology are also relevant for other nuclear science students, and vice versa.

During STAR lifespan, STAR provided three education courses and two training courses:

- One week PhD course on Environmental Radiobiology, run each year since 2013 in June by NMBU. Course details available here. In 2013, there were 28 attendees, 9 that took the final exam to get the 5 ECTS.
- Two week MSc course on Experimental Radioecology, run each year since 2013 in October by NMBU. In 2013, there were 16 attendees, 13 that took the final exam to get the 10 ECTS.
- Two week MSc course on Radioecology, run each year since 2013 in October together with the Experimental Radioecology course, 5 ECTS, at NMBU.
- Three day training course in Mixture Toxicity, held in January 2014 by SCK•CEN, 9 attendees.
- Three day training course in Environmental Protection, held in April 2014 by CEH, 18 attendees.

For some of the courses, exams were arranged at home universities.

For all courses, the student participation increase in 2014 compared to 2013 of more than 100 %. The feedback of students were very positive. More details on the evaluation of the courses can be found in D6.4 "Strategic Plan for Securing Long Term Sustainability for Education and Training in Radioecology" released in March 2015.

In addition to these above courses included in the STAR program, additional courses have been held:

- Several web-based courses on Biological Ligand Model (BLM) and mixture toxicity.
- A MSc course on Assessing Risk to Humans and the environment (10 ECTS) co-funded by DoReMi
- In partnership with COMET and the ALLIANCE, two refresher courses were held at the ICRER 2014 conference: ERICA tool and Noble gas modelling.

Other important activities include fostering links with the education and training activities in other areas including promoting radioecology through lectures on other Environmental Science Courses:

- Brit Salbu and Deborah Oughton gave lectures at the DoReMi MSc course on Epidemiology and Radioecology (part of the EU MSc in Radiobiology)
- Hildegarde Vandenhove gave a lecture at the DoReMi MSc course in Radiobiology on Radioecology and possible applications to Fukushima.
- Tom Hinton gave a lecture at a DoReMi workshop on strengthening collaborations among radiation biologists and radiation ecologists.
- Clare Bradshaw gave a number of lectures at radiobiology and ecology courses at Stockholm University
- Deborah Oughton gave a lecture at the EU Erasmus MSc course Environmental Pollution in Estonia, 43 students from 8 counties (www.eu-eip.eu)

STAR also mounted e-learning materials (videos; made during a meeting in Stockholm) onto the Radioecology Exchange. See the 'what is radioecology' on the home page and three videos describing DEBtox, Mixed contaminants and Biotic Ligand Modelling on the Virtual Laboratory here: https://wiki.ceh.ac.uk/x/5oBsD.

Students involved in STAR work, mainly contributed to WPs 3, 4 or 5. In total it is around 20 students from IRSN, SCK•CEN, SU, NMBU and SUNY who participated to STAR activities. Roughly half of them were MSc students with the remained being PhD or post-doc students.

A *PhD research school* was launched through the Radioecology Exchange website (https://wiki.ceh.ac.uk/display/star/STAR+PhD+Research+School) and 18 PhD students from STAR joined. The school was opened to the wider research community after the STAR Berlin meeting in July 2012, and was promoted at a number of upcoming conferences. The school was intended to promote networking between students and between students and potential employees, thorough arrangement of joint PhD courses, interactions with other training initiatives and promotion of internships with stakeholders.

In addition, two stakeholder workshops were arranged in Helsinki and Oslo, with the participation of 47 stakeholders from outside the STAR network. The first workshop, on education and training demand, was aimed primarily at potential employers, but with additional participation from experts who could provide insights into the overarching drivers for radioecology in society. The second workshop, on education and training supply, was aimed primarily at those who are engaged in education and training in the nuclear sciences.

3.3.2 Improving the competence of NoE partners

Three PIs were proposed to evaluate the relevance of improving the competence of the NoE partners:

- PI-18. Arranging specialist workshops;
- PI-19. # of attendees
- PI-20. feedback from attendees

Several specialist workshops were organised by STAR, either relevant for the RTD activities of STAR (in WP 3, 4 or 5). In all of these workshops, recognised international experts were invited to exchange with STAR partners. These workshops include:

- an International workshop on wildlife dosimetry (WP3) in June 2014, Madrid; https://wiki.ceh.ac.uk/x/14HHD). The workshop addressed a wide spectrum of questions related to the ionising radiation dose estimation in animals and plants, counting with world leading experts in each of the issues discussed. There were 30 participants from 12 countries (Belgium, Canada, France, Japan, Norway, Portugal, Russia, Spain, Sweden, United Kingdom and the USA).
- two Kd workshops, in collaboration with IAEA MODARIA WG4 (relevant for WP3). The first Kd workshop was held in May 2014 in Oslo and the second in Monaco in April 2015. Outputs are available from: https://wiki.ceh.ac.uk/x/u4XXD.
- the workshop on the state of the art of multiple stressor research, including a session on the Dynamic Energy Budget (DEB) theory held in May 2011, Mol (relevant for WP4 and 5). There were 37 participants, among which 6 international experts of multi contamination or of DEB theory.
- the expert consultation workshop to establish the final research and experimental programme of WP4 held in January 2012, Brussel (MS4.3). There were 24 participants.
- the workshop/training courses on Mixture Toxicity at SCK•CEN in Mol, in January 2014 (WP4). There were 9 attendees and 3 international experts among the lecturers.
- the workshop on transgenerational and epigenetic mechanisms of radiation toxicity at chronic doses (related to WP5) as a joint activity between STAR WP5 and COMET in December 2014, Oxford. The workshop addressed a wide spectrum of questions related to long-term and transgenerational exposure, in laboratory studies of radiation and chemical effects, molecular biology relating to epigenetic mechanisms, human and ecological risk assessment and radiological protection. World leading experts in each of the subjects attended the workshop. In total there were 48 participants from 12 countries (Belgium, Canada, USA, Spain, France, Germany, Japan, Norway, Portugal, United Kingdom, Russia and Sweden). Outputs are available from: https://wiki.ceh.ac.uk/x/u4XXD

Feedbacks from attendees were positive for all workshops.

3.3.3 Contribution of STAR to science policy

One PI was proposed to evaluate the relevance of the STAR contribution to science policy:

- PI-21. Incorporation of STAR generated results into National and International forums

STAR results were presented to international scientific conferences, among them:

- The Norwegian Society for Radiation Protection Conference, Reykjavík, 22-25 August 2011.

- The 2nd International Radioecology Conference (ICRER), Hamilton 2011, where STAR was given a 1.5 hour time slot in a special session on "the integration of international radioecological efforts" (23 June 2011).
- The 12th International Conference of the Biogeochemistry of Trace Elements (ICOBTE) conference, Athens, Georgia, USA; 2013 where STAR co-chaired the special symposium on "Environmental Radioactivity: Legacy Sites, Chernobyl and Fukushima" (with associated special issue of J. Environmental Radioactivity, vol. 131).
- The Society of environmental Toxicology and Chemistry (SETAC) conferences (SETAC North America 35th Annual Meeting, Vancouver 2014, SETAC Europe 34th Annual Meeting, Basel 2014 and SETAC Europe 35th Annual Meeting, Barcelona 2015) where research done under WP4 and WP5 were promoted through posters and oral presentations.
- The 4th Dynamic Energy Budget Symposium, Marseille 2015, where STAR research was promoted through oral presentations.
- The 3rd International Radioecology Conference (ICRER) in Barcelona, 2014, where STAR gave refresher training courses and promoted its research through posters and oral presentations (15 presentations)

In addition, several STAR participants are now on committees of the ICRP. STAR participants are also working on several IAEA programmes (EMRAS-ii and MODARIA) (see above section on "exploitation of results by end-users").

3.4 Management

3.4.1 Efficient and transparent decision making

Three PIs were proposed to evaluate the relevance of the efficient and transparent decision making:

- PI-22. Regular Steering Committee meetings and continuous interaction with partners
- PI-23. Evaluation by External Advisory Board
- PI-24. Timely publication of agendas and minutes on website

The two administrative bodies of STAR are the Management Team (MT) and the Steering Committee. The MT was the supervisory body responsible for executing the project. Formally, it is composed of the different WP leaders, plus the Coordinator. However, it was decided at the beginning of the project to open all the MT meetings to representatives of each STAR institute, even those that are not in charge of a WP. This way of conducting management decisions favoured integration and transparency among the STARs partners, as well as enhancing the flow of communication.

In the DoW, three MT meetings were scheduled per 18-month period. However, to improve the communication between partners, it was decided to increase the frequency of the MT meetings. For that purpose, IRSN bought a webvideo-conferencing system (Adobe Connect) improving the flow of communication and saving travel costs. ON average, MT meetings

were organised each 2 months. Overall, 31 MT meetings were held during the 54 months of the project, among them 7 were face-to-face meetings.

The SC was composed of one representative from each of STAR's partners, plus the Coordinator. It was the ultimate decision-making body of the NoE. Three SC meeting were organised during the project, as scheduled in the DoW. However, exchanges with the SC were not restricted to these meetings, as a lot of SC decisions were taken by e-mails (for example votes on allocation of flex funds).

For further details regarding the dates of these MT or SC meetings see deliverables reporting the three 18-month periods of STAR (D1.5; 1.9 and 1.12 respectively).

The evaluation of STAR was made thanks to an External Advisory Board. In the DoW only three meetings were planned with the EAB. A fourth one was adding for a better evaluation (meetings occurred in June 2011, June 2012, January 2014 and June 2015). After each meeting a report was provided by the EAB to the coordinator and forwarded to each WP leader. These reports were part of the "Performance report" released each 18-month (D1.4; D1.8 and D1.12). Overall, the evaluation of the STAR by the EAB was positive (see section 2 of this deliverable).

Agendas and minutes of the MT, SC or EAB meetings (monthly video-conferences or face-to-face) were all posted on the STAR members' wiki site.

3.4.2 Efficient and transparent operation

Five PIs were proposed to evaluate the relevance of the efficient and transparent operation of management:

- PI-25. Feedback from management team and steering committee meetings
- PI-26. Feedback from External Advisory Board
- PI-27. Accessibility of coordinator
- PI-28. Effectiveness of coordinator
- PI-29. Timely publication of agendas, minutes

No complaints from the MT or the SC occurred within the project. All STAR partners appreciated the efficiency of the web meetings that highly improved communications while conserving time, money and effort.

In their final report the EAB made some recommendations to the EC regarding the:

- Roles and Responsibilities of the EAB: The EAB could be of greater value to the EC and be of greater assistance the Grantees if the EC were to publish formal guidance on the roles, responsibilities and EC expectations for an EAB. It would be important to identify, for example, if the EC expects the EAB to be more of an oversight group or if they are to partner with the Grantee to advance the project. It would also be important to identify the responsibilities of the Grantee to respond to and take action in response to EAB recommendations and comments.
- Performance Indicators: The EC is moving from tracking metrics (e.g., Deliverable, Milestones and number of published papers) to monitoring performance indicators.

The use of performance indicators is a new approach and concept for Grantees and the use of performance indicators, instead of metrics, has not been incentivized. It would benefit the EC and Grantees for the EC to publish formal guidance on Performance Indicators and incentivize their use by Grantees.

The coordinator has been readily accessible during all the project life. The coordinator has fulfilled all his/her administrative, financial and managerial obligations in a timely manner in that:

- the Consortium Agreement was established within the first 6 months of the project, and further amended when new beneficiaries entered the consortium
- all funds (prefinancing and interim payments) have been distributed to partners in a timely manner
- all deliverables have been submitted to the EC as soon as they were produced
- The agenda and minutes of all meetings organized within WP-1 have been dealt with through efficient e-mail exchanges.

3.4.3 Coordination with EC

Two PIs were proposed to evaluate the relevance of the coordination with EC

- PI-30. Effective communication with EC
- PI-31. Obligations delivered according to the Grant Agreement

Communication with the EC's representative is fluid and without problems

STAR's commitments, according to the Grant Agreement, with the European Commission, have been met on-time and as promised. The GA has been amended twice: one in 2014 for the entry of two new beneficiaries in the STAR consortium (it included also some other minor amendments) and one for the change of coordinator's name in 2015. Further details on the content of these amendments are provided in D1.11 *"Periodic Report for the 36-54 month period"* released in July 2015.

3.4.4 Financial Aspects

Two PIs were proposed to evaluate the relevance of the financial aspects of the coordination:

- PI-32. Prompt allocation of funds to partners
- PI-33. Transparent record keeping
- PI-34. Effective use of flexibility budget

The pre-financing allocated by the EC for STAR was received by IRSN on December 2010, prior to the official start date of STAR (1 February 2011). It corresponded to an amount of 1 933 215.20 €. A first allocation of the pre-financing was delivered to each partner on February 2011, at the beginning of the project. The second part of the pre-financing was allocated to each partner in December 2011, with the amounts allocated based on a Steering Committee decision.

The first interim payment (1 239 340.43 €) was received by IRSN on February 2013. The funds were allocated to each STAR partner according to their costs declaration for the first period in April 2013.

The second interim payment (224 857.67 €) was received on July 2014. The funds were allocated to each STAR partner on October 2014 according to their costs declaration for the second period and accounting for the amount already received as prefinancing plus first interim payment.

Following the EC acceptance of the amendment to the GA relative to the entry of two new beneficiaries in the consortium in November 2014, the coordinator distributed the prefinancing due to SUNY and TOKAI on December 2014. Because these two partners entered the consortium very late in the third period, the STAR SC voted to distribute 80 % of the total EC allocation as pre-financing to these two partners.

The flexible budget has been used effectively and efficiently for enlarging the consortium to new members, and for tasks not initially planned in the DoW, but of high added-values for the STAR work. D 1.10 *"Flex fund report"* released in in companion to this report details the allocation of this budget task by task. The allocation of the flex funds was voted on by the STAR SC.

All financial transactions were made in transparent manner between STAR partners. The update of the budget has been presented regularly by the coordinator at MT meetings.

3.4.5 Develop a culture of team spirit with high ethical standards

Two PIs were proposed to evaluate the relevance of the development of a team spirit culture with high ethical standards

- PI-35. A survey will be designed to query STAR participants on an annual basis. The survey will target questions that pertain to team spirit and ethics Prompt allocation of funds to partners
- PI-36. An on-line short course will be developed to teach ethics in science to students and young professionals Transparent record keeping

To promote a culture of scientific excellence, innovation, team spirit, and high ethical standards, as well as the success and long term sustainability of this NoE, the Coordinator initiated a newsletter to inform STAR partners about the latest news and achievements.

The Coordinator recognised the similarity of attempting to integrate portions of each STAR partner's organisation to that of a corporate merger in the business sector. Lacking such experience, the Coordinator obtained the assistance of the Aix-Marseille Business School. Five Master of Business Administration (MBA) students developed a "change management" strategy for STAR and instructed the STAR coordinator in some appropriate business principals dealing with corporate mergers. The MBA students developed a questionnaire and queried the STAR participants on aspects of change management and the developing Network of Excellence. STAR's External Advisory Board considered the assistance of the business school a positive task of WP-1

3.5 Integration

3.5.1 Researcher mobility

Two PIs were proposed to evaluate the relevance of researcher mobility:

- PI-37. # of visits to other partners/labs
- PI-38. ease of access to shared infrastructures

As part of the work on stimulating researcher mobility, a set of criteria have been drafted for partner use of the mobility stimulus budget. To be viable the activity should facilitate active collaboration and integration between STAR partners, by supporting exchange of scientists and students between partner institutions. It should entail a visit of at least 3 days, preferably longer. The budget does not cover attendance of STAR meetings and short workshops. A more detailed description is available in MS report MS6.4 *"Mobility Strategy"*. These were discussed and ratified at the EAB/WP6 meeting in Berlin (June 2012).

Scientist and student mobility has been supported by

- student exchange between SU and NMBU (participation of two PhD students in experiments, 3 weeks);
- joint experiments on *C. elegans* between IRSN and NMBU (two NMBU scientists visiting IRSN for 1 week) and IRSN, NMBU and NERC-CEH (scientists from NMBU and IRSN visiting NERC-CEH for 1 week)
- WP5 IRSN experiments with the gamma-irradiation facility of SU (September 2012, 1 post-doc),
- WP4 and 5 SU and IRSN experiments with the gamma-irradiation facility of SCK•CEN (January 2013 and November-December 2013, 2 PhD students),
- STUK and SCK•CEN students attending a STAR radioecology training course in Norway (October 2013)
- one NERC-CEH researcher, who spent two periods of six and two weeks respectively at IRSN for consolidating Kd databases in 2014-2015

As demonstrated by the exchange above, infrastructures were made easily accessible to STAR partners. The infrastructures used so far included the gamma-irradiation facility at SCK•CEN, the gamma-irradiation facility at SU, the gamma-irradiation facility at NBMU, as well as IRSN and NERC-CEH laboratories.

3.5.2 Integration of RTD activities

Three PIs were proposed to evaluate the relevance of the integration of RTD activities

- PI-39. # of new members to the ALLIANCE
- PI-40. # of joint publications
- PI-41. # of joint research projects

During STAR lifespan, the ALLIANCE expanded from 8 founding members to 21 members from 14 countries (http://www.er-alliance.eu). The first ALLIANCE annual workshop was held in Madrid in the end of April 2014 in connection with the General Assembly.

Among the 30 STAR publications (see annex 2), 12 are co-authored by members of at least two STAR institutes.

STAR partners are involved in at least two joint research projects: the COMET project, funded under the EC-7th programme and started in June 2013 and the CONCERT project, funded under H2020 and started in June 2015.

3.5.3 Sustainability after EC funding

Three PIs were proposed to evaluate the relevance of the sustainability after EC funding

- PI-42. Effective merger of STAR into the ALLIANCE
- PI-43. Effective response to other calls for proposals
- PI-44. Expansion of ALLIANCE with new members

The legal status for the ALLIANCE was completed in September 2012. It formed as an association governed by the French law of 1st July 1901. Later, the ALLIANCE strengthened its connection with the four radiation protection platforms (ALLIANCE, MELODI, NERIS and EURADOS) by the signature of a joint Memorandum of understanding in December 2013.

A framework assuring the sustainability of STAR outputs have been created through the establishment of the COMET (Coordination and iMplementation of a pan-European instrumenT for radioecology) and CONCERT projects.

Started on 1st June 2013, COMET will strengthen the pan-European research initiative on the impact of radiation on man and the environment by facilitating the integration of radioecological research, including both the human foodchain and the protection of wildlife. The project builds upon, and complements, the foundations laid by the ALLIANCE and STAR. By collaborating with the European platforms on nuclear and radiological emergency response and recovery (NERIS) and low dose radiation risk (MELODI), and relevant training networks (e.g. EUTERP, ENEN) COMET will significantly aid preparation and implementation of an integrated radiation protection programme under Horizon 2020. The COMET consortium expands on the organisations of STAR and the ALLIANCE. In particular, COMET facilitates links with countries which have experienced major nuclear accidents (i.e. former Soviet Union states and Japan).

CONCERT is the newly established European Joint Programme (EJP) instrument. It is formed as a consortium with 28 partners, 4 European research platforms (including the ALLIANCE), and 20 linked third parties, to develop a sustainable structure for joint programming and open research calls in the field of radiation protection in Europe. CONCERT started in June 2015 and the first call is planned for early 2016.

ALLIANCE expanded from 8 founding members in 2012 to 21 members, from 14 countries.

4 Annexes

4.1 Annex 1. Summary of STAR accomplishment per WP

SUMMARY of Work Package 2

Integration and Infrastructure

1. **WORK PACKAGE:** WP-2; Integration and Infrastructure

2. **WORK PACKAGE LEADER:** Tarja Ikäheimonen (tarja.ikaheimonen@stuk.fi)

3. **TIME PERIOD COVERED BY SUMMARY:** February 2011 to July 2015

4. **MILESTONES ACHIEVED:**

N°	Title	Delivery date	Comments
MS 2.1	Consortium Workshop for facilities and other infrastructure	09/03/2011	Meeting agenda and summary
MS 2.2	Consortium meeting on integration and SRA	18/05/2011	Meeting agenda and summary
MS 2.3	Selection criteria for the European Observatory sites	26/01/2012	Report
MS 2.4	Consortium workshop for facilities and other infrastructures	24-26/04/2012	Workshop agenda and summary
MS 2.5	Consortium meeting on integration and SRA	12-13/11/2012	Meeting agenda and summary
MS 2.6	Selection of the European Observatory site(s)	30/11/2012	Evaluation report
MS 2.7	Preparatory workshop for creating management structures and long-term funding	15-17/04/2013	Workshop agenda and summary
MS 2.8	Consortium meeting on integration and SRA	13-16/01/2014	Meeting agenda and summary
MS 2.9	Consensus meeting on future work	14/01/2015	Meeting agenda and summary
MS 2.10	Preparatory workshop for creating management structures and long-term funding	14/01/2015 9-11/06/2015	Final dissemination event 9-11/06/2015 - see meeting agenda and summary

5. **DELIVERABLES ACHIEVED:**

N°	Title	Delivery dates
2.1	Strategic Research Agenda – first version	13/04/2012
2.2	Joint Infrastructure - Description	25/07/2012
2.3	Observatory for Radiological Research - Description	31/03/2013
2.4	Virtual Laboratory - Description	29/05/2013
2.5	Strategic Research Agenda - Updated version	21/02/2014
2.6	Final plan for integration and the long term SRA	Due to 31/07/2015

6. **COMPREHENSIVE LIST OF ACCOMPLISHMENTS**:

The first Radioecology Strategic Research Agenda

Virtual laboratory

Infrastructure catalogue

Radioecological observatories

Long-term integration -> the Radioecology Alliance, COMET, CONCERT etc.

7. **STATEMENT OF THE EUROPEAN ADDED VALUES OF THE ACCOMPLISHMENTS**:

Establishing and maintaining the Strategic Research Agenda

The first Strategic Research Agenda (SRA) (D2.1, Apr12), which provides a long term vision (15-20 years) of radioecological research needed, was created. It was updated taken into account the comments from stakeholders and experts and by adding a new strategic part focusing on Education and Training challenges, the associated vision and key action lines (D2.5, Jan14). Next version, which will be published soon, will include a new part dealing with Infrastructures. The SRA has been already proved to be valuable as it was utilized when a joint stakeholder survey on priorities for radiation protection research were launched by the ALLIANCE, NERIS, MELODI and EURADOS in mid June 2014. This survey focused on the synergistic research priorities identified by the four platforms, which were used as the bases of the topics of the second OPERRA call in Dec 2014. The above mentioned research platforms will continue developing and updating their sectorial SRAs in the CONCERT EJP regularly in perennial or annual cycles. Identified research priorities will directly serve as input for coming open calls arranged by CONCERT EJP.

It was originally planned that STAR would prepare the roadmap associated to this SRA. However, this task is done under the COMET project. The radioecology SRA was completed by a preliminary roadmap produced by COMET (Deliverable 2.1), with the help of STAR and the endorsement of the ALLIANCE. Research topics for radioecology were prioritized within this preliminary roadmap in part to include areas relevant for post-emergency management, low-dose effect and dosimetry research. At present, seven working groups have been launched aiming to build a 5-year roadmaps. The six topical WG are dealing with: marine radioecology, NORMs sites, forest radioecology, human food chains modelling, inter- and intra-species radiation sensitivity and transgenerational effects. A 7th topical WG is under development (atmospheric radionuclides and transfer processes).

The SRA has clearly supported the joint research by defining the common goal for radioecological research. Without that goal the work would be fragmental and the use of our (declining) resources wouldn't be optimized. Without the SRA the radioecological research could have been left out of the CONCERT EJP - that is left without EC funding.

Virtual laboratory

The Virtual Laboratory is a space within the Radioecology Exchange (www.radioecology-exchange.org) website established by STAR. The aim of the Virtual Laboratory is to provide openly available information to encourage integration through joint research and joint use of infrastructure. The anticipated audience varies from interested 'members of the public' through to radiation protection specialists.

The Virtual Laboratory provides information on methods and procedures, facts and datasheets, radioecology models as well as lectures and videos. It will also begin to establish the integrated use of data and sample materials within the network and also by the wider community. The virtual laboratory is a one tool to ensure a sustainable workforce in radioecology, which is the ultimate aim of the education and training parts of STAR.

Infrastructure catalogue

To ensure effective collaboration and integration, inventory of infrastructure covering equipment, methods, bioinformatic equipment and methods, sample archives, models, expertise and facilities for radioecological research was created. The list of the facilities available for others is in the public domain of the Radioecology exchange under "Virtual laboratory, Equipment and facilities". The infrastructure survey showed that STAR partners and the ALLIANCE members have a high-quality infrastructure, extended expertise and competence for radioecological research in Europe. No specific lack of know-how was identified.

To best utilise existing resources, the emphasis is on promoting the visibility and joint use of existing infrastructures - and this is what the infrastructure catalogue does. The infrastructure catalogue is a useful tool for partners to search for skills and services the other partners have to offer. It is useful for potential new ALLIANCE partners in both directions; new partners will know ALLIANCE capabilities and partners in ALLIANCE can identify which capabilities are missing within the STAR/ALLIANCE. The

information in the database could also be used for coordination and integration in response to emergencies and it can be utilized for training and mobility (i.e. by identifying where one partner can send staff to be trained by another partner). The infrastructure database supports collaboration between STAR/ALLIANCE and other research organisations, international organizations (e.g. IAEA) and other platforms (NERIS, HERCA, MELODI). The ongoing work on identifying key infrastructure for radiation protection research in Europe and beyond will continue under CONCERT EJP.

In order to get radioecology infrastructure databases more useful the infrastructure data needed to be made open for larger community. Facilities available for others either as commercial services or through research collaboration need to be extended. Now it includes only the STAR partners. The data in the infrastructure database must also be up to date. By this the way, we can maintain the value of infrastructure catalogue in the future.

As pointed out above, the infrastructure catalogue is a useful tool for both project planning and long-term development of radioecological research: (new/old) partners can search for skills and services the other partners have to offer and the ALLIANCE can identify which capabilities are missing in Europe.

Radioecological Observatories

One of the novel ideas for integration was the creation of Observatories for Radioecological Research. Radioecological Observatories are contaminated field sites that provide a focus for long term joint field investigations. Three contaminated sites has been selected as the most promising options as Radioecological Observatories sites: areas near Chernobyl, a previous coal mining and processing site in Poland and a forest in the Fukushima prefecture in Japan, affected by the accident at the Fukushima Dai-ichi NPP (under EC COMET project). The characteristics of the Observatory sites in the Upper Silesian Coal Basin (USCB) and in the Chernobyl Exclusion Zone (CEZ) have primarily been derived from scientific literature.

The progress under STAR project has not been as fast as expected:

- Following a site visit in the Polish Observatory site in August 2014 it became clear that contamination levels at the site may be too low to allow for the creation of an observatory site. The STAR partners agree that the set of Radioecological Observatories should include a NORM site, preferably located in Europe, since such sites provide mixed contaminant situations (radionuclides and heavy metals). Efforts to identify alternative NORM sites have not yet been successful. The major problems are missing long-term perspectives and access restrictions.
- Concerning the CEZ the next step will be to define smaller areas that are suitable to address the research lines prioritized in the SRA and the implementation plan currently being developed under COMET. The political situation in Ukraine may impact the access and use of the Observatory Site though current STAR/COMET members are conducting research there.

Despite the difficulties, the observatory sites have enhanced collaboration between the partners. As the work progressed, valuables lessons were learned e.g. on selection process and access to the sites: The selection process was an interesting combination of formal process and discussions. Also

the use of external experts helped to broaden the view and to identify aspects that the group members are not aware of. Reaching consensus on a complete list of clearly defined criteria is one of the most important and most difficult parts of the group decision making process. Regarding the access to the sites, obtaining permissions might be difficult and time-consuming. Site owners' attitudes towards research in general, their individual interests and their economic situation might play an important role.

There is still confidence in the observatory sites. The pooled, consolidated effort will maximize the sharing of data and resources as well as provide excellent training and education sites. All data collected from the Observatory sites will be made accessible from the Radioecology Exchange and result in a valuable international data set.

Long-term integration

Integration of the European radioecology community is underway with the help of STAR partners. The ALLIANCE, officially formed as an association in September 2012, expanded from the initial eight founding members (BfS, CIEMAT, IRSN, NERC, NRPA, SCK•CEN, SSM, STUK) to 21 members from 14 countries. The first ALLIANCE annual workshop was held in Madrid in the end of April 2014 in connection with the General Assembly. COMET project (Coordination and iMplementation of a pan-European instrumenT for radioecology) started at 1st June 2013 and build upon the foundations laid by the ALLIANCE and STAR will continue to strengthen the pan-European research initiative on the impact of radiation on man and the environment by facilitating the integration of radioecological research. This proves that STAR has made considerable progress in enhancing the long term stability and sustainability of radioecology in Europe.

As leaving alone nowadays means leaving without funding, the four platforms (ALLIANCE, MELODI, NERIS and EURADOS) have strengthened their connections. They all signed a joint Memorandum of understanding in December 2013. STAR/COMET partners as representatives of the ALLIANCE have participated in several meetings arranged by the other platforms. The four platforms were working together for the H2020 European Joint Programming –call in Sep 2014 (joint CONCERT proposal) and for the second OPERRA call (Dec 2014).

The work to promote radioecology will continue under CONCERT: The CONCERT proposal sent to H2020 EJP call in Sep 2014 was accepted. There are 52 partners in the consortium including research platforms ALLIANCE, MELODI, NERIS and EURADOS. CONCERT aims to develop a sustainable structure for promoting and administration of joint programming and open research calls in the field of radiation protection research for Europe. Activities of the CONCERT consortium will focus on (i) the aspects of support to develop an integrated landscape for radiation protection research in Europe and (ii) to directly fund coordinated research projects in an open, fair and transparent manner dedicated to state of the art science and tailored to the radiation protection needs of the society, authorities and stakeholders. Integration of education and training in the research agenda as well as optimal use of research infrastructures in Europe and even beyond are essential for the consortium.

As pointed out above, STAR has made considerable progress in enhancing the long term stability and sustainability of radioecology in Europe. The collaborative work and joint research strengthens radioecology and enables us to achieve the goals set together. We have managed to integrate even further than we imagined in the beginning of the project.

8. LIST OF PUBLISHED PAPERS:

- Hinton, T.G., Garnier-Laplace, J., Vandenhove, H., Dowdall, M., Adam-Guillermin, C., Alonzo, F., Barnett, C., Beaugelin-Seiller, K., Beresford, N.A., Bradshaw, C., Brown, J., Eyrolle, F., Février, L., Gariel, J.-C., Gilbin, R., Hertel-Aas, T., Horemans, N., Howard, B.J., Ikäheimonen, T., Mora, J.C., Oughton, D., Real, A., Salbu, B., Simon-Cornu, M., Steiner, M., Sweeck, L., Vives i Batlle, J. 2013. An invitation to contribute to a strategic research agenda in radioecology *Journal of Environmental Radioactivity* 115: 73-82.

- Hinton, T.G., Garnier-Laplace, J., Vandenhove, H., Dowdall, M., Adam-Guillermin, C., Alonzo, F., Barnett, C., Beaugelin-Seiller, K., Beresford, N.A., Bradshaw, C., Brown, J., Eyrolle, F., Fevrier, L., Gariel, J.C., Gilbin, R., Hertel-Aas, T., Horemans, N., Howard, B.J., Ikaheimonen, T., Mora, C., Oughton, D., Real, A., Salbu, B., Simon-Cornu, M., Steiner, M., Sweeck, L., Vives i Batlle, J. 2013. Una invitacion para contribuir a la agenda estrategica de investigacion en radioecologia *Radioproteccion* 74: 48-61

Conference proceedings:

- Steiner M., Urso L., Wichterey K., Willrodt C., Beresford N.A., Howard B.J., Bradshaw C., Stark K., Dowdall M., Liland A., Eyrolle-Boyer F., Guillevic J., Hinton T., Gashchak S., Hutri K-L., Ikäheimonen T., Muikku M., Outola I., Michalik B., Mora J.C., Real A., Robles B., Oughton D., Salbu B., Sweeck L., Yoschenko V. 2014. Radioecological Observatories – Breeding Grounds for Innovative research, *3th International Conference on Radioecology & Environmental Radioactivity, Barcelona, Spain, 7-12 September 2014*.

- Muikku, M., Bradshaw, C., Dowdall, M., Garnier-Laplace, J., Hinton, T., Howard, B.J., Ikäheimonen, T.K., Outola, I., Real, A., Salbu, B., Steiner, M., Vandenhove, H. STAR – Strategic network for integrating radioecology. 2011. *In: Proceedings of Current Challenges in Radiation Protection. XVI NSFS Conference, Reykjavík, 22-25 August 2011*.

SUMMARY of Work Package 3

Integrated Human and Non-human Radiation Protection

1. **WORK PACKAGE:** WP-3; Integrated Human and Non-human Radiation Protection

2. **WORK PACKAGE LEADER:** Astrid Liland (astrid.liland@nrpa.no)

3. **TIME PERIOD COVERED BY SUMMARY:** February 2011 to July 2015

4. **MILESTONES ACHIEVED:**

N°	Title	Delivery date	Comments
MS 3.0	Summary of ongoing activities and projects in the area of integrated protection	01/09/2012	Compilation on the wiki
MS 3.1	Parallel FEP analysis for humans and wildlife for hypothetical sites/Scenarios	30/03/2012	Internal report on FEP analysis, on the wiki
MS 3.2	Complete Interaction Matrices for humans and wildlife for the hypothetical sites /scenarios	01/05/2013	Internal report on Interaction Matrices, on the wiki
MS 3.3	Description of coupled combined model for humans and wildlife	01/03/2013	Model description report, on the wiki
MS 3.4	Internal report on comparative analysis of human and non-human frameworks	01/07/2013	Internal report, on the wiki
MS 3.5	Report analysing both FEP and IM analysis with respect to a conceptual model for integrated risk ass	month 38	Internal report on FEP and IM, on the wiki
MS 3.6	To have completed literature reviews and theoretical evaluations of extrapolation techniques	19/02/2013	Presentation of evaluation at Month 30 workshop, on the wiki
MS 3.7	International workshop on wildlife dosimetry	10-12/06/2014 worskshop in Madrid + summary -month 44	Workshop agenda and summary, input to D3.2
MS 3.8	To have tested the feasibility of the selected and developed extrapolation techniques	month 44	Deliverable 3.2 published
MS 3.9	Report on methods for wildlife dosimetry	30/09/2014	Report on the open web site
MS 3.10	Complete sample collection	Due 30/09/2014, cruise performed as planned in September 2014	80% of freeze-dried samples from Japan received by May 2015.
MS 3.11	Complete Stable Isotope Aanalysis (SIA)	Due 31/12/2014, SIA	SIA raw data, available on

	and analyses of samples	completed May 2015, rest to follow soon	wiki
MS 3.12	Data analyses	Due 31/03/2015, not delivered	This data report will be part of D3.5 instead of a stand alone report

5. DELIVERABLES ACHIEVED:

N°	Title	Delivery Date
3.1	Tier-1 Model	31/03/2015
3.2	Feasibility of robust extrapolation techniques	25/09/2014
3.3	Wildlife Dosimetry Workshop	13/10/2014
3.4	Feasibility Report of improving a model for integrated protection of humans and wildlife	Due 31/07/2015
3.5	Report on fluxes and trophic transfer of radiocaesium in marine ecosystems	Due 31/07/2015

6. COMPREHENSIVE LIST OF ACCOMPLISHMENTS:

The most important output has been the development of a joint screening model for humans and biota. The CROM8 code was released for public use in April 2015 where human risk assessment and environmental risk assessment can be performed via different modules within the same tool. It is based on the earlier versions of CROM for human risk assessment, with some revisions, and the ERICA Tool for environmental risk assessment. CROM8 does not contain all the functionalities of the ERICA Tool, yet is still a powerful tool for integrated risk assessment.

The next generation of the CROM code will be entirely new and will be named CROMERICA. This code will implement the revised models of the IAEA (i.e. replacement to SRS19), the updated version of STAR MS3.3 'Integrated Screening Model for Humans and Wildlife – Initial Description', and advances in the parameters in the ERICA Tool. This new tool will implement state-of-the-art approaches for improvements in performance, usability and maintainability. CROMERICA will maintain all features of CROM8, including the biota and human integration, uncertainties calculations or graphical capabilities, while following a design concept which allows for easy extension, quality control and maintenance. The final product will be a tool that can be further expanded by community developers, for including their own models and creating new user interfaces. This creates a flexible dose assessment platform that can be further expanded by new users for including their problems. An alpha version of CROMERICA will be presented at the final event of STAR in June 2015. Further development will continue after the end of STAR and users and developers courses will be organised.

Several actions were undertaken in WP3 to support the development of an integrated tool:

- The use of Features, Events and Processes (FEPs) analysis together with Interaction Matrices (IMs) (MS 3.1, 3.2 and 3.4, poster in Aix)
- The reflection on the feasibility of integrating the human and environmental frameworks on a conceptual level (MS 3.4, presentation in Aix, article in preparation)
- Feasibility of iteratively improving a model for integrated protection by mechanistically modelling key processes (D3.4, poster in Aix)
- Extrapolation techniques (MS 3.6 and 3.8 and D 3.2, poster and presentation in Aix)
- Wildlife dosimetry (MS 3.9 and D 3.3, poster in Aix, article in preparation)

As part of the last action, STAR organised a wildlife dosimetry workshop with international experts in May 2014. It addressed a wide spectrum of questions related to wildlife dosimetry. World leading experts from 12 countries presented state-of-the-art scientific achievements (https://wiki.ceh.ac.uk/display/star/Wildlife+Dosimetry+Workshop) and participated in discussions on four main topics:

- Internal dosimetry and biokinetics in wildlife
- Wildlife dosimetry fit for purpose
- Uncertainties in wildlife dosimetry
- What improvements are needed in wildlife dosimetry and why?

The summary of the conclusions can be found here: https://wiki.ceh.ac.uk/download/attachments/214401495/Discussion%20Sessions_MINUTES.pdf?version=1&modificationDate=1405669238000&api=v2

Fukushima research was introduced in the STAR project following an open call on this issue. Task 3.5 on fluxes and trophic transfer of radiocaesium in marine ecosystems off Fukushima has brought new insight into marine radioecology, in particular the role of sediments as a sink and secondary source of contamination of fish. MS312 and D3.5 will combined to one report delivered by 31 July 2015, where all the conclusions of this part of STAR will be summarised.

7. STATEMENT OF THE EUROPEAN ADDED VALUES OF THE ACCOMPLISHMENTS:

WHY: The human and environmental radiation protection frameworks have evolved somewhat independently and created parallel radiological protection systems over the preceding years. They diverge in many respects like end points, sophistication of dosimetry, dose limits/consideration levels etc., but the underlying dispersion and transport processes are the same. Indeed, the dispersion of radionuclides in the environment would be the same regardless of whether the end point of the risk assessment is humans or biota or both, since the underlying physical and chemical processes are independent of the species that are exposed. A risk assessment tool that could combine human and biota calculations in the same code would give

more coherence to risk assessment for a given scenario. For regulators, a combined tool would be more resource-efficient than to perform assessments for humans and biota separately with two different tools for the same site.

WHAT: The CROM 8 and CROMERICA developed in cooperation with STAR, allows the user to perform dose assessments for both humans and biota in the same code via different modules. The underlying dispersion and transfer models would be the same for both, yet allowing different end points to be addressed. An alpha version of CROMERICA will be demonstrated during the STAR final event.

The reflection on the possible integration of the radiation protection *frameworks* (as opposed to only the risk assessment) has highlighted the possibilities and challenges to such an approach. This will be presented in Aix and in a journal article under preparation. In short, using the same dispersion and transfer models is justified while challenges remain for e.g. protection endpoints, availability of transfer data, sophistication of dosimetry, spatial and temporal variability influencing transfer and exposure, and availability of relevant data on dose-effect relationships

IMPACT: The reflection and work on the integration issue has significantly benefited from a joint European effort. The STAR partners have different fields of expertise (ecosystem approach, dosimetry, modeling, extrapolation techniques, environmental chemistry etc.) that contributed to a more holistic view of the topic. FEPs and IMs in particular benefit from a discussion among a larger group of various experts to ensure all relevant elements are included. Integration of modelers in human risk assessment with modelers in biota risk assessment was the key to develop the integrated codes CROM8 and CROMERICA with the associated parameter values. The latter were improved by new experimental data and extrapolation techniques from several STAR experts. For the radiation dosimetry of animals and plants, the European community benefited from cooperation with other international experts, facilitated by STAR through an international workshop. A number of peer-reviewed articles have been (and will soon be) published based on the work in WP3 and will thus reach a larger audience internationally.

SUSTAINABILITY: The reflection on the integration of the radiation protection frameworks for humans and biota (article in prep.) can serve as input to the larger radiation protection community in the development of new recommendations for protection.

The CROMERICA development will continue after STAR ends, as cooperation between several institutes and the IAEA, led by CIEMAT. The software will be made freely available to any interested user and can as such serve both European and international needs. CIEMAT has an excellent track record of leading the continuous development of the CROM code. We expect this to continue for CROMERICA, in particular because the ERICA Tool developers are now well

integrated with the CROM developers thanks to STAR. Of course, the need for some future funding is clear, mainly for arranging users and developers courses or if specific development needs appear. This will be addressed in Aix.

8. PROBLEMS ENCOUNTERED:

The WP leader was changed after 2 years. This caused some delays around mid-term, yet did not influence on the final deliveries.

The partners included after the open call, did not have experience in participating in EC projects. In addition, they were included late in the project since the negotiations with the EC were bureaucratic and protracting in time. As a result, the integration was somewhat limited between these new partners and the original partners. The deliveries in WP3.5 were delayed because of the EC protracted procedure, but SUNY and TOKAI expect to deliver a full report on the Fukushima research by the end of STAR.

9. LIST OF PUBLISHED PAPERS:

1. Beresford N.A., Wood M.D., Vives i Battle J., Yankovich T.L., Bradshaw C., Willey N. 2015. Making the most of what we have: application of extrapolation approaches in radioecological wildlife transfer models. *Journal of Environmental Radioactivity* available on line doi:10.1016/j.jenvrad.2015.03.022 [Open access]
2. Hinton T.G, Byrne M.E., Webster S., Beasley J.C. 2015. Quantifying the spatial and temporal variation in dose from external exposure to radiation: a new tool for use on free-ranging wildlife. *Journal of Environmental Radioactivity* 145: 58-65.
3. Liland A. Modeling of radionuclide distribution in contaminated nuclear and NORM sites. In: Leo van Velzen (Ed.). *Environmental Remediation and Restoration at Contaminated Nuclear and NORM Sites*, pp. 115-142. Woodhead Publishing Series in Energy: Number 71, Oxford, UK, February 2015. ISBN: 978-1-78242-231-0 (print), 978-1-78242-238-9 (online).
4. Beresford N.A., Wood M.D. 2014. A new simplified allometric approach for predicting the biological half-life of radionuclides in reptiles. *Journal of Environmental Radioactivity* 138: 116-121
5. Brown JE, Hosseini A, Dowdall M. 2014. On the application of an environmental radiological assessment system to an anthropomorphic surrogate. *Integrated environmental assessment and management* 10 (1), 125-132.
6. Chaplow J.S., Beresford N.A., Barnett C.L. 2014. Post Chernobyl surveys of radiocaesium in soil, vegetation, wildlife and fungi in Great Britain. *Earth Syst. Sci. Data Discuss.* 7, 693-711.
7. Beresford N.A., Vives i Batlle J. 2013. Estimating the biological half-life for radionuclides in homoeothermic vertebrates: a simplified allometric approach. *Radiation and Environmental Biophysics* 52: 505-511.

8. Beresford N.A., Yankovich T.L., Wood M.D., Fesenko S., Andersson P., Muikku M., Willey N.J. 2013. A new approach to predicting environmental transfer of radionuclides to wildlife: A demonstration for freshwater fish and caesium. *Science of The Total Environment* 463–464: 284-292.
9. Brown J.E., Beresford N.A., Hosseini A. 2013. Approaches to providing missing transfer parameter values in the ERICA Tool – How well do they work? *Journal of Environmental Radioactivity* 126: 399-411
10. Fisher N.S., Beaugelin-Seiller K., Hinton T.G., Baumann Z., Madigan D.J., Garnier-Laplace J. 2013. Evaluation of radiation doses and associated risk from the Fukushima nuclear accident to marine biota and human consumers of seafood. *Proceedings of the National Academy of Sciences of the United States of America* 110 (26): 10670-10675.
11. Hosseini A., Stenberg K., Avila R., Beresford N.A., Brown J.E. 2013. Application of the Bayesian approach for derivation of PDFs for concentration ratio values. *Journal of Environmental Radioactivity* 126: 376-387
12. Howard B.J., Wells C. Beresford N.A., Copplestone D. 2013. Exploring methods to prioritise concentration ratios when estimating weighted absorbed dose rates to terrestrial Reference Animals and Plants. *Journal of Environmental Radioactivity* 126: 326-337
13. Howard B.J. 2013. A new IAEA handbook quantifying the transfer of radionuclides to wildlife for assessment tools. *Journal of Environmental Radioactivity* 126: 284-287
14. Psaltaki M., Brown J.E., Howard B.J. 2013. TRS Cs CRwo-water values for the marine environment: analysis, applications and comparisons. *Journal of Environmental Radioactivity* 126: 367-375
15. Wood M.D., Beresford N.A., Howard B.J., Copplestone D. 2013. Evaluating summarised radionuclide concentration ratio datasets for wildlife. *Journal of Environmental Radioactivity* 126: 314-325
16. Brown J.E., Hosseini A., Seymour C. 2011. Modelling transfer to animals accounting for trans-generational factors. *Radioprotection* 46(6):S509–S514.

SUMMARY of Work Package 4

Radiation Protection in a Mixed Contaminant Context

1. **WORK PACKAGE:** WP4: Radiation Protection in a Mixed Contaminant Context

2. **WORK PACKAGE LEADER:** Hildegarde Vandenhove, hvandenh@sckcen.be

3. **TIME PERIOD COVERED BY SUMMARY:** February 2011 to July 2015

4. **MILESTONES ACHIEVED:**

N°	Title	Delivery date	Comment
MS 4.0	Summary for WP2 about actual and future R&D activites in multiple stressor studies by partners	09/02/2012	
MS 4.1	Report of expert workshop to get acquainted with the state of the art of multiple stressor research	18/06/2011	Workshop was held in month 4 (May 25-27 2011; final minutes available 1 month later)
MS 4.2	Review of approaches for exposure and effects assessment and draft proposal for research programme	26/11/2011	Workshop minutes of workshop held 7-8/11/2011
MS 4.3	Expert and stakeholder consultation and final integrated research programme	27/03/2012	Integrated research plan developed based on Critical review (D4.1) and expert consultation at May and Nov 2011 and Jan 2012 meetings. Available at: https://wiki.ceh.ac.uk/download/attachments/125534772/Milestone+43+Experimental+plan+final.pdf
MS 4.4	Interim report on theoretical model runs to test effect of mixed contaminant conditions on exposure	29/02/2012	Milestone 4.4 is covered in D4.1
MS 4.5	Interim report on availability/exposure related lab/field R&D and model runs and updated R&D plan	31/03/2013	Midterm results from lab/field research and model run outcomes.

MS 4.6	Parameterization of DEB model for all test organisms subjected to mixed exposure conditions	Delayed.	Delayed due to dismissal of a PhD student at SCK•CEN working on the research and to a too optimistic scheduling. A Postdoc then started 1 June 2013. Postdoc has left SCK•CEN meanwhile (1/3/2015) and has so far not yet produced a written document on the parameterization of the DEB model for *Lemna*. A draft paper is being worked on and when finalized, this paper can be viewed as MS 4.6. Some parts of the works done on *Lemna* have already been published in the D5.4 of WP5. For *C. elegans* the work is accomplished as expected.
MS 4.7	Interim report on effects related lab R&D and model runs and updated R&D plan	30/08/2013	Midterm results from lab research
MS 4.8	Interim report on availability/exposure related lab/field R&D and model runs and updated R&D plan	01/11/2014	Midterm results from lab/field research and model run outcomes
MS 4.9	Interim report on effects related lab R&D and model runs and updated R&D plan	01/08/2014	Midterm results from lab research
MS 4.10	Mixed contaminant workshop and roadmap for future R&D	10/06/2015	Workshop/meeting agenda and summary The WP4 panel discussion at the STAR final event will replace the workshop.

5. DELIVERABLES ACHIEVED:

N°	Title	Delivery date
4.1	Review of methods in ecotoxicology for mixed exposure	27/03/2012
4.2	Tools for assessing availability and exposure in a multiple contaminant context	Due May 2015
4.3	Tools for mechanistic understanding of induced effects for mixed exposure	Due May 2015
4.4	Critical Evaluation	Due 31/07/2015

6. COMPREHENSIVE LIST OF ACCOMPLISHMENTS:

Five (+three) papers already published (submitted); several more papers in quality journals (ES&T, Env. Pollut, etc.) are in draft phase or in early preparation phase (see annex).

1. WP4 – Task 1: Critical review of existing approaches, methods and tools for mixed contaminant exposure, effect and risk assessment in ecotoxicology and evaluation of usefulness for radioecology
   - Summarized in D4.1 which also formed basis for development of a detailed research plan.

2. WP4-Task 2: Testing the feasibility and applying existing approaches and tools for robust RN bioavailability assessment under mixed contaminant conditions

   2. Establish whether co-contaminants have significant impact on the speciation and thus the availability of the radionuclides. Geochemical modelling of four U and Th-impacted waters was carried out using different geochemical speciation models. No general effect of co-contaminants on uranyl or thorium speciation was found, with the exception of a small effect of the presence of iron(III) colloids on uranyl speciation in slightly acidic water. WHAM7 was selected for use in developing Biotic Ligand Models (BLM) for uranyl (species) and the WHAM-7 database was amended where required and made available to the WP4-partners. Paper submitted and accepted with minor revision.

   3. Development of a Uranium BLM for aquatic organisms under mixed contaminant conditions
      - Model developed for salmon (*Salmo salar*) (NMBU), *Daphnia magna* (IRSN) and *Lemna minor* (SCK•CEN, STUK and BfS). Experiments were set up in which the toxicity of U was tested in media varying in proton levels or in one of the major cations (Ca, Mg, K, Na). For *S. salar* pH has clearly the most significant influence on uranyl accumulation and toxicity. For *D. magna* significant effects of pH, Na, Mg and Ca on uranyl toxicity have been found. For *L. minor*, effects of Mg, Ca and pH on accumulation and toxicity can be seen.
      - A spread sheet tool has been developed to address fitting of BLM parameters to the data.
      - A two-site BLM for accumulation and toxicity was developed for *S. salar*, based on trends in the sublethal accumulation of U on the gill and on mortality. The model described the variability in toxic endpoints well, predicting 17 LC50s, with overall variation 1.5 orders of magnitude, to within a factor of three. Trends in the effects of uranium-cadmium, mixtures covering a range of concentrations and ratios, were predicted reasonably well.
      - A two-site BLM for accumulation and toxicity was developed for *L. minor*, based on trends in tissue accumulation and on growth inhibition. The model described trends in accumulation and effects well. Where EC50s were calculable the model generally predicted them to within a factor of three, except in harder exposure waters. Trends and magnitudes in uranium/cadmium mixture effects were generally well predicted.
      - A single site BLM, with multiple binding species, was developed for *D. magna* based on mortality. The model described the variability in toxic endpoints well, predicting LC50s, with overall variation two orders of magnitude, to within a factor of two. Trends and magnitudes in uranium/cadmium mixture effects were generally well predicted.
      - Generally, trends in uranium toxicity and their relationship to uranium chemistry are more complex than are typically seen for non-radionuclide metals such as copper or cadmium. Patterns of accumulation and toxicity for *S. salar* and *L. minor* were broadly similar and showed differences at high and low pH, requiring a BLM with two binding sites. Patterns of toxicity for *Daphnia magna* were subtly different and a different model structure was used. Trends in mixture effects were generally well described, suggesting that accounting for competition between uranium and metallic co-contaminants using a BLM-type approach has considerable promise.

3. WP4-Task 3: Apply selected approaches developed in ecotoxicology to assess the impact of mixed contaminant conditions on radiation induced effects and improve the understanding of underlying mechanisms and processes

- Binary mixture exposure experiments applying classical ecotoxicological settings and CA/IA.
  - Developed for external gamma irradiation + Cd and U(VI) + Cd; some combined exposure experiments were also performed with fluoranthene.
  - Experiments set up with *C. elegans* (IRSN), *L. minor* (SCK•CEN), *Salmo salar* (NMBU), phyto- and zooplankton (SU).
  - Based on initial datasets and analysis more targeted experimental designs have been established that better take into account the limitations imposed especially around the logistics of the radiation source exposure facilities and effects. The problems with exposure logistics have been the lack of low to mid-dose effects and the difficulties in getting the spacing for the high doses close to the source to accommodate the required number of samples.
  - The main general pattern observed has been that
    - Joint effects are always present regardless of endpoint/timepoint measured and species
    - Interactions are also common but these depend more on endpoint measured
    - Examining a range of endpoints / timepoints allowed the identification of sensitive endpoint(s) and timepoint(s), and therefore better understanding of underlying processes and risk
    - From a risk assessment perspective, the most important thing to ascertain is whether there are potential interactive effects (especially synergistic):
      - CA and IA models are consensual scientific support for component-based Cumulative Risk Assessments under the assumption of zero interactions, and provide a basis for the consideration of mixtures with radioactive substances. Using those consensual concepts, the developments of an Ecological Risk Assessment framework for mixtures including radionuclides will remain consistent with the general ERA framework. However, integration in regulation is still needed.
      - We hardly identified strong synergistic effects (interactive effects were common, and almost always antagonistic)
      - Including bioavailability (competitive uptake) with BLM models explained most of apparent antagonisms (and allows revealing 'real' toxicokinetic /dynamic interactions)
      - Once 'bioavailability' interactions are considered, an overall conclusion for a species is possible using TKTD models, eg. DEBtox to derive an overall No Effect Threshold and conclusion on interactions
    - However, our results did not answer all the issues in support to the development of an ERA
      - Our experiments were performed at quite high exposure levels, and we mainly observed joint effect (where both stressors are toxic): possible interactions at low doses remain a question.
      - Interactions may remain at higher level of organization (trophic/population) and long term exposures that were not address in the performed experiments

- Development of a Mix-DEBtox for *C.elegans* and *L. minor*.
  - For *C. elegans*

- The data on U and Cd obtained from CA/IA experiments were used to explore the underlying mechanism of interaction with the support of DEBtox modelling.
- Simulations have successfully described the toxicity of U and Cd alone, consistent with previous DEBtox modelling for U and Cd.
- To describe the combined effects of U and Cd, an interaction term was considered in the various physiological parameters of the model.

- For *Lemna minor,* no Mix-DEBtox model will be developed: the development of a DEB and DEB-tox model took longer than expected.

7. STATEMENT OF THE EUROPEAN ADDED VALUE OF THE ACCOMPLISHMENTS:

INTEGRATION

a. Increased integration of the research groups in Europe dealing with research in multiple stressors (MS) in an ionising radiation context. Increased integration of experimentalists and modellers.
   → important since MS experiments are very demanding and require a multidisciplinary approach and shared infrastructure (chemistry, (molecular)biology, geochemical modelling, effects assessment models, irradiation facilities and facilities to work with radioactivity, …).

TOOLS AND DATABASE DEVELOPMENT

b. Good experimental and modelling practice developed (experimental and modelling tool box) which will be communicated to the broader public via the Radioecology exchange.
   →Important since review of past experiments[1] demonstrated that MS experiments involving radiation or exposure to radionuclides were not always performed according to an optimal experimental set-up and approach and effects assessment was not always optimal either. Our toolbox will direct scientists to adequate experiment set-up, experiment execution and data assessment.
   We have established an important dataset of new high-quality data which are available for others for additional analysis upon request. This data set can be amended with future datasets to enlarge the Radioecology Alliance data repository.
   → will allow for future more robust predictions/conclusions and/or such larger dataset will help in evaluating/demonstrating the robustness of our findings.

SCIENTIFIC ADVANCES

c. Our research has demonstrated that co-contaminant effects on mobility of uranyl and thorium series radionuclides in water appear to be minor even if for the scenarios tested, the concentration of co-contaminants was generally non-negligible.
   →Implies that in further research we can better concentrate on how the other contaminants affect bio-availability and toxicokinetic/toxicodynamics of radionuclides.
   →importance of a comprehensive, up to date database of complex formation constants when using geochemical speciation modelling was illucidated, which is an important message to the users of these tools.

[1] Vanhoudt, N., H. Vandenhove, A. Real, C. Bradshaw, K. Stark. 2012. A review of multiple stressor studies that include ionising radiation. Environmental Pollution 168:177-92.

d. The science done in STAR close to the forefront of efforts to explain mixture toxicity using BLMs. We not only studied such effects but also quantifying them for predictive purposes in BLMs. Following on from the development of BLMs for single species, the mix-BLM models allowed for interpreting the observed U/Cd mixture effects in terms of competitive uptake of the toxicants.
→ demonstrates the importance to obtain information about speciation in exposure media as well bioaccumulation, when linking exposure to effects.

e. Studies done under STAR represent the majority of the existing studies of uranium and radiation ecotoxicology in the species used. They additionally have the added value of including these novel data alongside other stressors as well as considering them in environmentally plausible mixture exposure scenarios, even if the doses are high
→ important in terms of establishing possible interaction and joint effect mechanisms and principles.

f. We showed that processes interacting at different levels may result in deviation of mixture effects from the reference model (CA, IA) predictions: (1) Interactions in the media that change the environmental availability of one or more chemicals; (2) Interactions at site of uptake and/or elimination of the chemical from the organisms that result in modulation of the total accumulated internal concentration of one or more mixture components; (3) Interactions at the target site that affect the binding of one or more chemicals to a receptor through which toxicity is (partly) mediated.
→important since it shows that both environment, toxicant and biological receptor are important in effect assessment. Mixture toxicity should best be assessed by dynamic and biology based methods and testing efforts should be directed towards more mechanistic understanding. In this way, the gene expression data have demonstrated to increase our understanding of single and combined effects by merging information from several toxic pathways.

ADVANCES FOR RISK ASSESSMENT

g. For the scenarios tested and based on the presently available data, we could demonstrate that effects observed could be predicted using CA/IA or deviations thereof.
→Implies that we can predict mixture toxicity from single compound data based on the MS impact models that were developed in the domain of ecotoxicology. Our work confirms that for sites containing mixtures of pollutants including radionuclides, regulation on a case for case basis for the single chemicals present may underestimate the ecosystem effects on multiple stressor exposures.

h. With our results we demonstrated interactive effects. Although we found mostly antagonism, some synergistic interactions were however also found (e.g. in *Lemna* and salmon). The number of scenarios, test organisms and MS combinations that could be tested in frame of this project were limited and conclusions should be confirmed by additional experiments.
→STAR has put the basis and created the interactive and integrative framework for future studies which link Cumulative Risk Assessment predictions, and validate their conservatism, with in situ observed toxic effects under a multi-contamination context that includes radionuclides (including robust exposure data, including bioavailability).

VISIBILITY

i. A high (expected) publication record will increase the visibility of the EC supporting these activities and will trigger further research in this area (important since we could only begin to explore this field within STAR).

8. LIST OF PUBLISHED PAPERS:

Horemans N., Van Hees M., Saenen E., Van Hoeck A., Smolders V., Blust R., Vandenhove H. 2015. Influence of nutrient medium composition and growth related endpoints on uranium toxicity in *Lemna minor*. *Journal of Environmental Radioactivity*, accepted for publication

Horemans N., Van Hees M., Van Hoeck A., Saenen E., De Meutter T., Nauts R., Blust R., Vandenhove H. 2015. Uranium and cadmium provoke different oxidative stress responses in *Lemna minor* L. *Plant Biol* 17:91-100.

Lofts S., Fevrier L., Horemans N., Gilbin R., Bruggeman C., Vandenhove H. 2015. Assessment of co–contaminant effects on uranium and thorium speciation in freshwater using geochemical modelling. *Journal of Environmental Radioactivity*, in revision.

Margerit A., Lecomte-Pradines C., Svendsen C., Frelon S., Gomez E., Gilbin R. 2015. Nested interactions in the combined toxicity of uranium and cadmium to the nematode *Caenorhabditis elegans. Ecotoxicology and Environmental Safety* 118: 139–148.

Nascimento F.J.A., Svendsen C., Bradshaw C. 2015. Combined effects from gamma irradiation and fluoranthene exposure on carbon transfer from phytoplankton to zooplankton. Submitted to Environmental Science & Technology

Song Y., Salbu B., Teien H-C., Heier S.L., Rosseland B.O., Høgåsen T., Tollefsen K.E. 2014. Hepatic transcriptomic profiling reveals early toxicological mechanisms of uranium in Atlantic salmon (Salmo salar). *BMC Genomics* 15:694

Song Y., Salbu B., Teien H-C., Heier S.L., Rosseland B.O., Tollefsen K.E. 2014. Dose-dependent hepatic transcriptional responses in Atlantic salmon (Salmo salar) exposed to sublethal doses of gamma radiation. *Aquatic Toxicology* 156: 52–64

Van Hoeck A., Horemans N., Van Hees M., Nauts R., Knapen D., Vandenhove H., Blust R. 2015. Characterizing dose response relationships: chronic gamma radiation in *Lemna minor* induces oxidative stress and altered polyploidy level. Submitted to Journal of Environmental Radioactivity

Annex 1 – Expected list of papers for WP4

What	#	Who	Title	Status	Expected submission date
Task 1	1	CEH	Stephen Lofts, Fevrier Laureline, Horemans Nele, Gilbin, Rodolphe, Bruggeman Christophe, Vandenhove Hildegarde, Assessment of co-contaminant effects on uranium and thorium speciation in freshwater using geochemical modelling, *Journal of Environmental Radioactivity*	Accepted with minor revision	May 2015
Task 2 BLM	2	SCK•CEN	Horemans Nele, Van Hees May, Saenen Eline, Vandenhove Hildegarde Influence of pH on U-toxicity in *Lemna minor (*paper considers toxicity endpoints)		June 2015
	3		Horemans Nele, Van Hees May, Saenen Eline, Vandenhove Hildegarde Influence of different cations on U-toxicity in *Lemna minor*		June 2015
	4		Horemans Nele, Van Hees May, Saenen Eline, Willrodt Christine, Turtiainen Tuukka, Vandenhove Hildegarde, Lofts Steve, Setting up a biotic ligand model for U in *Lemna minor*		Jul 2015
	5		Horemans Nele, Van Hees May, Saenen Eline, Willrodt Christine, Turtiainen Tuukke, Vandenhove Hildegarde, Lofts Steve, Influence of Cd on the U-toxicity measured on effects on a U-biotic ligand model in *Lemna minor* *4 and 5 may be combined*		Jul 2015
	6	IRSN	Février L., Miko mi Ondo L., Lecomte T., Gilbin R. Influence of Hardness and pH on uranium bioavailability to *Daphnia magna, to be submitted September 2015* (includes Cd)		Dec 2015
	7		Février L., Miko mi Ondo L., Lecomte T., Gilbin R., Lofts S. Development of a biotic ligand model for uranium in *Daphnia magna, to be submitted September 2015* (includes Cd) *6 and7 may be combined*		Dec 2015
	8	NMBU/ NRPA	Teien H-C., Thørring T., Skipperud L. Lind O.C., Salbu B., *et al*. The influence of pH and cation concentration in water on Uranium uptake in Atlantic salmon (*Salmo salar*)		Summer 2015

	9		Teien H-C., Hertel-Aas T., Thørring T.,. Kiel Jensen L., Oughton D., Salbu B., *et al*. Speciation, uptake and toxicity of uranium in Atlantic Salmon (Salmo salar)		Summer 2015
	10		Teien H-C., Brede D., Ayalew Kassaye Y., Thørring T., Kiel Jensen L., Skipperud L., Salbu B., *et al*. Influence of U on Cd toxicity in Atlantic salmon (Salmo salar)		Summer 2015
	11		Teien H-C., Lofts S. Biotic ligand model for U in Atlantic Salmon (*Salmo salar*) and the influence of Cd		Summer 2015
	12	CEH	U-BLM and influee of Cd – interspecies similarities/differences; review what is done in STAR as a short paper		Autumn 2015
Task 3 CA/IA	13	SCK•CEN	Horemans, N., Van Hees, M., Van Hoeck, A., Saenen, E., De Meutter, T., Nauts, R., Blust, R., Vandenhove, H. (2014) Uranium and cadmium provoke different oxidative stress responses in *Lemna minor L*. Plant Biology, DOI: 10.1111/plb.12222	Published	Jan 2015
	14		Van Hoeck A., Horemans N., Van Hees M., Nauts R., Knapen D., Vandenhove H., Blust R. Characterizing dose response relationships: chronic gamma radiation in Lemna minor induces oxidative stress and polyploidy level	Submitted	May 2015
	15		Horemans N., Van Hees M., Saenen E., Van Hoeck A., Smolders V., Blust R., Vandenhove H. Use of the Lemna minor growth inhibition test to study dose dependent effects of uranium in aquatic plants	Accepted	April 2015
	16		Horemans N., Van Hees M., Saenen E., Van Hoeck A., Vandenhove H. and Svendsen C. Metal uptake and toxic growth effects in Lemna minor exposed to varying mixtures of uranium and cadmium		June 2015
	17		Horemans N., Van Hees M., Saenen E., Van Hoeck A., Vandenhove H. and Svendsen C. Influence of ionising radiation on the toxicity of Cd in Lemna		Summer 2015
	18		Horemans N., Van Hees M., Saenen E., Van Hoeck A., Vandenhove H. The effect of a seven day recovery period on the toxicity of gamma, Cd and U induced in Lemna minor		Summer 2015
	19	IRSN	Margerit A., Svendsen C., Lecomte C., Frelon S., Gomez E., Gilbin R. Nested Interactions in Uranium and Cadmium Combined Toxicity to the nematode *Caenorhabditis elegans*. Ecotoxicol Environ Saf. 2015 Aug;118:139-48.	Accepted	April 2015
	20	NMBU/	Teien H-C., Brede D., Ayalew Kassaye Y., Skipperud L., Salbu B., *et al*. Characterizing dose response		Autumn 2015

		NRPA	relationships: chronic gamma radiation effects in Atlantic salmon (*Salmo salar*) developing embryos		
	21		Teien H-C., Brede D., Ayalew Kassaye Y., Skipperud L., Claus S., Salbu B., *et al*. Influence of ionising radiation on the toxicity of Cd in Atlantic salmon (Salmo salar) developing embryo (includes Cd)		2015/2016
	22		Brede D., *et al*., Gamma radiation and hepatic transcriptional responses in Atlantic salmon (Salmo salar) embryos		Autumn 2015
	23	SU	Nascimento F.J.A., Svendsen C., Bradshaw C. Combined effects from gamma irradiation and fluoranthene exposure on carbon transfer from phytoplankton to zooplankton. Submitted to Env. Sc.Technol.	Submitted	April 2015
	24		Nascimento F., Svendsen C., Bradshaw C. Effects of binary mixtures of gamma irradiation and the PAH fluoranthene on the transfer of carbon between phytoplankton and zooplankton		Summer 2015
	25		Bradshaw C., Meseh D.A., Alasawi H., Qiang M., Nascimento F. Combined effects of gamma irradiation and cadmium on cellular and population-level endpoints of the microalga *Pseudokirchneriella subcapitata*		Summer 2015
	26		Bradshaw C and Nascimento F. Combined effects from gamma irradiation and fluoranthene exposure on carbon transfer from phytoplankton to zooplankton.		Summer 2015
	27	IRSN	'*Common patterns in CA/IA response observed among organisms tested*"		
Task 3 DEB	28	IRSN	Margerit A., Gilbin R. (associated to NERC, authors to be confirmed). DEBtox modeling of the combined effects of U and Cd to the growth and reproduction of *Caenorhabditis elegans*		Sept 2015
Task 4 Evaluation	29	ALL	Robustness of radiation protection values under mixture conditions		Autumn 2015

SUMMARY of Work Package WP5

Ecologically Relevant Low Dose Effects

1. **WORK PACKAGE:** WP-5; Ecologically relevant low dose effects

2. **WORK PACKAGE LEADER:** Frédéric Alonzo (frederic.alonzo@irsn.fr)

3. **TIME PERIOD COVERED BY SUMMARY:** February 2011 to July 2015

4. **MILESTONES ACHIEVED:**

N°	Title	Delivery Date	Comments
MS 5.0	Produce a summary of WP2 about what has been done in low dose effects to nonhuman biota by partners	31/01/2012	summary of past & on going "in-house" projects
MS 5.1	Propose a method to collect info on life history traits and agree on population modelling	30/03/2011	Done during the Kick-off meeting and define within the minutes of the WP5 specific meeting
MS 5.2	Decide the sets of experiments, establish common guidance, discuss past/ongoing projects per partner	03/06/2011 and 10/07/2011	Done during the Mol meeting and refine during the WP5 extra meeting in Hamilton in June 2011 (see the minutes)
MS 5.3	Test the pop model sensitivity to life traits, justify the lab selected species and endpoints	30/09/2011	List of species/endpoints for experiments decided as a basis for D5.1. Pilot study performed at IRSN with the contribution of UMB in September 2011.
MS 5.4	Organise a session on DEB theory applied to single stressor, connected to WP4	26/05/2011	Mol meeting, well in advance compared to the initial deadline due to merging with WP4 needs
MS 5.5	Acquire dose rate – response relationships in lab for gamma and alpha	July 2014	Publication of gamma radiation effect data in *Daphnia* (in complement of the existing dataset for alpha from the ERICA programme). Presentation at the Final Dissemination meeting in Aix en Provence on 10/06/2015.
MS 5.6	WP5 meeting for intermediate evaluation if results and adjustments of R&D programme if needed	30/06/2012	See the minutes from WP5 specific meeting in Berlin

MS 5.7	Explore omics response for one threshold dose rate giving significant effect	First results presented at the Data Workshop in Vienna on 21/04/2015 – a fraction of analyses still on going.	Internal report as a basis for D5.3. Delays to obtain omics responses for chronic gamma and alpha in the same species, due to same reasons as MS55
MS 5.8	WP5 meeting for intermediate evaluation of results and adjustements of R&D programme if needed	10/06/2013	See the minutes from WP5 specific meeting in Tromso
MS 5.9	Apply DEB-tox on lab data sets, identify the mode of action for gamma & alpha	Initial results in nematodes presented the WP5 meeting in Berlin in July 2012 – Analyses in *Daphnia* presented at the Final Dissemination meeting in Aix en Provence on 10/06/2015	Internal report as a basis of D5.4 Plan included in D5.4. Analyses included in D5.5.
MS 5.10	WP5 meeting for intermediate evaluation of results and adjustements of R&D programme if needed	03/04/2014	See the minutes from WP5 specific meeting in Stockholm
MS 5.11	WP4&5 joint meeting on system ecotoxicology, apply to WP5 effects data sets	10/12/2014	Workshop COMET/STAR in oxford
MS 5.12	Use data from observatory sites to test new group-specific protection criteria	31/01/2015	Analyses presented at the Final Dissemination meeting in Aix en Provence on 10/05/2015. Results as a basis for D5.5

5. DELIVERABLES ACHIEVED:

N°	Title	Delivery Date
5.1	Plan for laboratory radiation effects studies	02/11/2011
5.2	Life history traits, radiosensitivity and population modelling: methods to extrapolate from individual endpoints to population dynamics	06/08/2012
5.3	Radiation Quality report	03/12/2013
5.4	Modes of Action	20/08/2014
5.5	Protection Criteria	Due 31/07/2015 (no expected

		delay)

6. **COMPREHENSIVE LIST OF ACCOMPLISHMENTS**:

A	**Conduction of alpha and gamma radiation experiments**, using on a **common experimental plan** (described in Deliverable report 5.1). Experiments were: i. shared among partners: nematodes studies at SCK•CEN with IRSN collaborators (Jan and Nov 2013) and at IRSN with NMBU collaborators (Sept 2011); parallel Zebrafish studies at IRSN (June 2013) and UMB (Oct 2013); ii. performed by single institutes: studies in plants at SCK•CEN, in daphnids at IRSN and salmons at NMBU.
B	**Acquisition of new experimental data** on **survival, growth and reproduction effects** over **full life cycles** during **chronic multigenerational** exposure to **gamma and alpha** radiation in **animal and plant** species: ii. in the duckweed *Lemna minor* (gamma radiation – technical problems with alpha); v. in the crustacean *Daphnia magna* (gamma radiation in completion of existing effect data from alpha radiation); v. in the nematode *Caenorhabditis elegans* (gamma radiation only);
C	**Acquisition of new experimental data** on **molecular and cellular responses** to chronic radiation: vi. in *Arabidopsis thaliana* and the zebrafish *Danio rerio* (alpha and gamma radiation); ii. in *D. magna* and *C. elegans* (gamma radiation only).
D	Successful applications of the **DEBtox approach** (Dynamic Energy Budget theory applied to Toxicology): ii. to analyze **gamma radiation** effects in *C. elegans*; x. to explain **transgenerational changes** in depleted uranium effects in *Daphnia*; x. to compare **gamma and alpha radiation effects** in *Daphnia*; Preliminary fits in *L. minor*.
E	Successful application of **a classic population modelling approach** (Leslie matrices): xi. to extrapolate radiation effects measured in laboratory organisms to population-level endpoints and calculate population risks in 12 species representing 4 taxonomic groups (including aquatic and soil invertebrates, fish and mammals) ii. to test population risk for a fish group, by exploring the diversity in population responses among 21 fish life cycles.

7. STATEMENT OF THE EUROPEAN ADDED VALUES OF THE ACCOMPLISHMENTS:

STAR WP5 demonstrated the capacity of radioecotoxicology for integrating (scientific objectives, approaches etc.) not only among European radioecologists, but also with the wider international ecotoxicology community of chemicals.

A	STAR WP5 demonstrated a **capacity for sharing objectives, approaches, facilities** among partners to address radiation effects in a diversity of biological models.
B	STAR WP5 brought **new knowledge for the robustness of ecological risk assessment of ionizing radiation**, while the **EC current approach** is limited by the **lack of data on chronic radiation effects**, in amount and relevance, in terms of: i. range of addressed endpoints in each species; ii. range of tested species to cover biodiversity; ii. range of tested life stages, where full life cycles should be tested; v. exposure of a single generation, where multigenerational exposure is more relevant; v. exposure to external gamma only, where comparisons among radiation types are needed (gamma, alpha…etc.)
C	STAR WP5 concomitantly measured **toxic effects** at various levels of biological organization (**molecular, cellular, histological, physiological, organism**), bringing valuable data to understand **mechanisms** of (chemical and radiological) toxicity and to test **biomarkers** relevance for both ecotoxicology and radioecology.
D	**Novel developments** in **DEBtox** modelling for both ecotoxicology and radioecology: vi. in *C. elegans* and *Daphnia*, first applications to **the case of ionizing radiation**, involving an new dose metrics (dose rate as an internal concentration); ii. in *Daphnia*, use of a **transgenerational damage compartment** to mechanistically explain changes in effects across generations and link molecular alterations to effect intensity; ii. in *Lemna*, contribution to the ongoing development of a **DEB model for plants**.
E	A **significant methodological progress** for the field of radioecotoxicology (nothing new, however, compared to research in the field of ecotoxicology): x. Test of theoretical population risk levels in 12 laboratory species at the international reference benchmarks; x. population modelling for radioprotection purpose at an initial step (mainly due to many

	extrapolations needed to fill data gaps) with much room for future improvements.

8. **LIST OF PUBLISHED PAPERS**:

Biermans G., Horemans N., Vanhoudt N., Vandenhove H., Saenen E., Van Hees M., Wannijn J., Vangronsveld J., Cuypers A. 2015. *Arabidopsis thaliana* seedlings show an age-dependent response on growth and DNA repair after exposure to chronic γ-radiation. *Environmental and Experimental Botany* 109: 122-130.

Parisot F., Bourdineau J.-P., Plaire D., Adam-Guillermin C., Alonzo F. 2015. DNA alterations and effects on growth and reproduction in *Daphnia magna* during chronic exposure to gamma radiation over three successive generations. *Aquatic Toxicology* 163: 27–36.

Vanhoudt N., Horemans N., Wannijn J., Nauts R., Van Hees M., Vandenhove H. 2014. Primary stress responses in *Arabidopsis thaliana* exposed to gamma radiation. *Journal of Environmental Radioactivity* 129: 1-6.

Lance E., Alonzo F., Garcia-Sanchez L., Beaugelin-Seiller K., Garnier-Laplace J. 2012. Modelling population-level consequences of chronic external gamma irradiation in aquatic invertebrates under laboratory conditions. *Science of the Total Environment* 429: 206-214.

SUMMARY of Work Package 6

Mobility, Training and Education

1. **WORK PACKAGE:** WP6; Mobility, Training and Education

2. **WORK PACKAGE LEADERS:** Lindis Skipperud (Lindis.Skipperud@nmbu.no) /Deborah H. Oughton (Deborah.oughton@nmbu.no)

3. **TIME PERIOD COVERED BY SUMMARY:** February 2011 to July 2015

4. **MILESTONES ACHIEVED**

N°	Title	Delivery Date	Comments
MS 6.1	Stakeholder workshop on current demands for training and education in radioecology	19-20/05/2011	Meeting completed, Helsinki, May 2011. See D6.1 and meeting agenda and participant list
MS 6.2	Stakeholder workshop on current training and education supply in radioecology	14-16/11/2011	Meeting completed, Oslo November 2011. See D6.1 and meeting agenda and participant list
MS 6.3	Research school website	July 2012	Website running and PhD students registered See https://wiki.ceh.ac.uk/x/BwHICQ
MS 6.4	Mobility strategy draft	June 2012	Presented and accepted at Berlin EAB/WP6 meeting.
MS 6.5	Draft training and education programme	April 2013	Available on the web portal. Objectives and deliverable are detailed in a document prepared by NMBU that highlights the key components needed within a radioecology education programme, based on input from 2 stakeholder workshops and NMBU's existing education programmes
MS 6.6	Revision of syllabus and test run training modules	March 2013	Course syllabus and Examination list. Participation list available on the wiki. Initially due month-30, but delayed because training conducted by CEH waited until new version of ERICA is issued
MS 6.7	Revision of syllabus and test run PhD module	August 2013	Course syllabus and Examination list PhD module) tested. Good student evaluation (D6.3)
MS 6.8	Revision of syllabus and test run MSc module	November 2013	Course syllabus and Examination list MSc modules (2) tested. Good student evaluation (D6.3)

MS 6.9	To have completed course module evaluation	July 2014	Course evaluation meeting with SCK•CEN and NMBU - Evaluation report given as part of the D6.3
MS 6.10	Strategy plan for education and training sustainability	February 2015	Internal report as a basis for D6.4

5. DELIVERABLES ACHIEVED:

N°	Title	Delivery Date
6.1	Stakeholders demand and educational supply	22/02/2012
6.2	Training and education platform structure	30/09/2013
6.3	Test run of course modules	27/03/2014
6.4	Securing long term sustainability for the training and education	26/03/2015

6. COMPREHENSIVE LIST OF ACCOMPLISHMENTS:

The following list of accomplishments can be given for the WP6:

- Stakeholders were involved from the very start of WP6 with the demand and supply workshops (Oslo, Norway and Helsinki, Finland 2011) with, in addition to STAR participants, a total of 47 stakeholders participating. We have tried to continue the engagement with the stakeholders by informing them of the syllabus revisions, including ways in which the revisions have been made according to stakeholder recommendations.
- Revised STAR course content and the overall Radioecology MSc syllabus.
- Successfully held five of the STAR E&T Courses (see below) with good student participation, which is more than a 100% increase on past attendance, with good student feedback. For some of the courses, exams were arranged at home universities.
- Increased mobility of both students participating and STAR experts teaching in the STAR courses.
- Stakeholders have also been kept informed of the STAR courses offered. Interaction with academic stakeholders has been good, with participation of students from a number of institutions outside of the STAR network (e.g. from US NCoRE).
- Two refresher courses have been held in collaboration with COMET at the ICRER conference 2014: ERICA tool and Noble Gas modelling.
- Aspects of radioecology E&T have been included into the SRA.
- Attracted co-funding from DoReMi to sponsor participation of additional students and foster links with the radiobiology community.
- Participated in MELODI/OPERRA E&T network meetings to initiate integration of the STAR E&T into OPERRA and Horizon 2020.
- Explored the procedures for awarding joint degree between different universities.
- Commenced work on designing a new radioecology modelling module
- Launch of E&T platform on the Radioecology Exchange website, linking to other E&T platforms (DoReMi, CINCH etc).

- Provided a comprehensive report on possible E&T sustainability (D6.4)
- The STAR WP has also retained a high international profile by interacting with other EU E&T networks (DoReMi, CINCH, EUTRAP, NERIS, etc) which will be essential for ensuring the integration of STAR and Radioecology in future EU projects and networks and especially in CONCERT. This is also fundamental for the sustainability of Radioecology E&T.

7. STATEMENT OF THE EUROPEAN ADDED VALUES OF THE ACCOMPLISHMENTS:

Overall the WP6 has had an important contribution to the education and recruitment of students to radioecology in Europe, as well as strengthening international recognition of the importance of radioecology as a relevant discipline for other areas of nuclear science. The significant increase in the number of students taking courses and registered for the Radioecology MSc was one of the main performance indicators set at the start of the project and this indicator has been met. Participation of STAR partners as lecturers on E&T courses as well as students from different STAR partner institutions was one of the underlying aims for mobility, and has also been met. Written examination of students at their home universities in Europe was also tested and successful. The refresher courses seem also most useful as a relatively high number of students and researches have attended for instance the refresher courses given during the ICRER meeting in Barcelona 2014.

The STAR WP has also retained a high international profile by interacting with other EU E&T networks (DoReMi, CINCH, EUTRAP, NERIS, etc) which will be essential for ensuring the integration of STAR and Radioecology in future EU projects (e.g., COMET) and networks and is especially important within the CONCERT JEP. This is also fundamental for the future sustainability of Radioecology E&T.

Stakeholders representing industry, authorities and academic have provided input to the E&T platform. They have also been informed about the STAR courses offered during the period. Interaction especially with academic stakeholders has been very good, with participation of students from a number of institutions both inside and outside of the STAR network. The possibilities of creating Joint MSc degrees in Europe have also been positively discussed among academic stakeholders, and will be continued within COMET.

Peformance Indicators:

1) To strengthen and secure a sustainable integrated European training and education platform in radioecology that will attract top-level graduates,
    - The “high-level” Website/platform makes radioecology more visible and is connecting with nuclear chemistry and radiobiology websites
    - Overview of courses available in nuclear science demonstrates that radioecology is of international importance
2) To maintain a relevant workforce that is in a position to meet future economic and societal needs within the nuclear sciences,
    - Revised courses given after interaction with stakeholders (relevance and quality)
    - Courses given intensive in order to allow access for a wider student base

3) To enhance the mobility of teachers and STAR scientists as a means of securing competence building.
    - Mobility funds for scientist has been available and used, and should continue in future projects
    - STAR scientist has been teaching in the different courses sharing their expertise with students
    - Student mobility – further initiatives (e.g., Erasmus Mundus) will be taken in COMET

8. LIST OF PUBLISHED PAPERS

There will be published at least two papers on STAR E&T work after the finalizing of STAR

9. LIST OF COURSES DONE (include n° of attendees)

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

- One week PhD course on Environmental Radiobiology, held in June 2013 by NMBU, 28 attendees, 9 that took the final exam to get the 5 ECTS.
- Two week MSc course on Experimental Radioecology, held in October 2013 by NMBU, 16 attendees, 13 that took the final exam to get the 10 ECTS. This course were repeated in 2014
- Two week MSc course on Radioecology, held in October 2013 together with Experimental Radioecology, 5 ECTS, at NMBU. This course was repeated in 2014.
- Three day training course in Mixture Toxicity, held in January 2014 by SCK•CEN, 9 attendees.
- Three day training course in Environmental Protection, held in April 2014 by CEH, 18 attendees.

In addition to these above courses included in the STAR program, additional courses have been held:

- Several web-based courses on Biological Ligand Model (BLM) and mixture toxicity.
- A MSc course on Assessing Risk to Humans and the environment (10 ECTS) co-funded by DoReMi
- In partnership with COMET and the ALLIANCE, two refresher courses were held at the ICRER 2014 conference: ERICA tool and Noble gas modelling.

SUMMARY of Work Package WP-7

Knowledge and Data Dissemination

1. **WORK PACKAGE:** WP7; Knowledge and Data Dissemination

2. **WORK PACKAGE LEADER:** Brenda Howard; (bjho@ceh.ac.uk)

3. **TIME PERIOD COVERED BY SUMMARY:** February 2011 to July 2015

4. MILESTONES ACHIEVED:

N°	Title	Delivery date	Comments
MS 7.1	NoE management Wiki	Feb. 2011	Management wiki sites established ahead of schedule, EAB and infrastructure/data holding collation sites also established for WP1 and WP2.
MS 7.2	Promote STAR at 2011 International Radioecology Conference	June 2011	A special session (seven presentations) promoting STAR was held at ICRER in Hamilton, Canada.
MS 7.3	To have defined database structures	Nov. 2011	Collaboration with WP2; Data holdings see: https://wiki.ceh.ac.uk/x/nwJvCg (log-in required) and https://wiki.ceh.ac.uk/x/DYFsD Infrastructure see: https://wiki.ceh.ac.uk/x/EQGsC (log-in required) and https://wiki.ceh.ac.uk/x/moeZD
MS 7.4	To have developed the structure of the Radioecology exchange ready for population	April 2011	See: www.star-radioecology.org and www.radioecology-exchange.org - Sites have been continually developed.
MS 7.5	Uploaded previous Euratom outputs	October 2012	Outputs are available on the Radioecology Exchange see: https://wiki.ceh.ac.uk/x/RYFsD

MS 7.6	To have produced target briefing documents on basic radioecology	May 2015	Factsheets on 20 key radionuclides prepared by CEH, CIEMAT, BfS, IRSN, NMBU and SU. See https://wiki.ceh.ac.uk/x/44BsD. An information sheet prepared by NRPA on marine radioecology is available from here: https://wiki.ceh.ac.uk/x/bQHoDQ
MS 7.7	Database and publication workshop and report	May 2014 (workshop), June 2014 (report)	Scope changed - delayed due to limited sharing of pre-STAR data by partners. This workshop focused on data for Kd and was held in collaboration with IAEA WG4 in Oslo in May 2014. Information on website: https://wiki.ceh.ac.uk/x/u4XXD
MS 7.8	Incorporation of social media outreach activities on web portal	Oct. 2011	Twitter (@STARadioecology) and Facebook (www.facebook.com/radioecology) accounts have been created and links to them added from www.star-radioecology.org and www.radioecology-exchange.org. News 'Blogs' available for all STAR members to post news items.
MS 7.9	To have published targeted e-learning packages on radioecology of key sources	Sept. 2014	Relates to e-learning packages produced for the T&E platform. Webpage created by CEH and populated by SU and NMBU. See https://wiki.ceh.ac.uk/x/poGuD
MS 7.10	Database and publications workshops and reports	April 2015	The 2nd workshop on Kd data follow up was held at the IAEA in Monaco in April 2015. The 3rd data workshop on making data available was held in Vienna in April 2015 prior to MODARIA WG4/8 meetings. Information on both these workshops is available: https://wiki.ceh.ac.uk/x/u4XXD

MS 7.11	To have developed finalised on-line database structure and functionality	Sept. 2014	The NERC-CEH Information Gateway is compliant with the European INSPIRE Directive and can be used to make data available. Currently all the data we have been made aware of is available from the links within the data information sheets here: https://wiki.ceh.ac.uk/x/DYFsD
MS 7.12	Dissemination via International Radioecology Conferences	Sept. 2014 and the Final dissemination event in Jun. 2015	Presentations on STAR activities were given at ICRER 2014, Barcelona (see: https://wiki.ceh.ac.uk/x/a4FiC) and ICOBTE 12 in Georgia, USA. Additional presentations were made at a range of national and international conferences/workshops Presentations and posters from the final dissemination event will be made available from the Radioecology Exchange and the STAR websites.

5. **DELIVERABLES ACHIEVED:**

N°	Title	Delivery Date
7.1	Web portal	27/02/2012
7.2	Dissemination Plan	End June but delayed to mid July 2015 to include dissemination event outcome
7.3	Online Databases	Due 31/07/2015

6. **COMPREHENSIVE LIST OF ACCOMPLISHMENTS**:

Web sites

- Webportal – Established the Radioecology Exchange (www.radioecology-exchange.org) as a gateway to access radioecological resources (D 7.1). The Radioecology Exchange is not project specific and will be maintained in the future via COMET and the ALLIANCE.
- Webportal – Established www.star-radiecology.org as a gateway to accessing the outputs of STAR (D 7.1)
- Creation and active maintenance of a radioecology news and careers blog – see side panel of the home page of the STAR and Radioecology Exchange websites (it is also

available on the COMET website). 'Old' news can be found here: https://wiki.ceh.ac.uk/x/U4FsD together with RSS feeds from the IAEA and the EC.

- Social media: set up a Twitter account - @STARadioecology and a Facebook account - https://www.facebook.com/radioecology
- Set up NoE management Wiki: https://wiki.ceh.ac.uk/x/CYB7Bw (log-in required)
- Set up STAR members infrastructure wiki (related to D 2.2) and data holdings wiki (used for data catalogue).
- Films made at meeting in Stockholm on the Radioecology Exchange (see the 'what is radioecology' video on the home page of www.radioecology-exchange.org and three videos describing DEBtox, Mixed contaminants and Biotic Ligand Modelling on the Virtual Laboratory here: https://wiki.ceh.ac.uk/x/5oBsD
- Enhanced contact with the other EC platforms web sites is anticipated via the ALLIANCE.

Access to radioecological information

- Created the Virtual Laboratory on the Radioecology Exchange See: https://wiki.ceh.ac.uk/x/BYG8D (Design & population of platform WP2 output (D2.4)) to enable easy access to methods, procedures and protocols some of which having been used in STAR experiments; created and collated facts, figures and data useful to radioecology and provided a brief overview of two radioecology models, CROM and ERICA.
- Created and made available 20 Radioecology Factsheets see: https://wiki.ceh.ac.uk/x/44BsD
- Begun to create a web page collating information related to Fukushima research such as information available on STAR (and COMET) partner websites and on those of major international organisations; see https://wiki.ceh.ac.uk/x/bQHoDQ (the page will be expanded during COMET)
- Created an information sheet (MS 7.6) on the consequences of marine releases after the Fukushima accident (available from: https://wiki.ceh.ac.uk/x/bQHoDQ.
- Collated and created easy access to historical EURATOM outputs see: https://wiki.ceh.ac.uk/x/RYFsD
- Created the Information Exchange, a web page: https://wiki.ceh.ac.uk/x/PIFsD to provide easy access to STAR (and COMET) partner publications, data catalogue, publication catalogues, newsletters, FAQ's and links to other websites of interest to radioecology
- Created access to observatory information on the Radioecology Exchange See: https://wiki.ceh.ac.uk/x/NoFsD (Related to D2.3). These pages will be expanded further during the COMET project.
- Recently made deliverables available through Researchgate which has greatly enhanced their availability and visibility. They are currently being downloaded frequently by followers.

Data

- Pioneered mechanisms to improve data transparency.
- Organised three workshops on radioecological data – two on Kd and one on data availability (related to MS 7.7 and MS 7.10 see above). The outputs from these workshops are accessible from: https://wiki.ceh.ac.uk/x/u4XXD
- Designed and set up a STAR members data holdings wiki; see: https://wiki.ceh.ac.uk/x/EwGsC (log in needed) - the information collated using this wiki was used to populate the data catalogue (see below)
- Defined, developed and populated the data catalogue to provide access to radioecology data currently held by partners (D7.3) see: https://wiki.ceh.ac.uk/x/DYFsD
- We will provide access (via the data catalogue) to data produced during STAR on the Radioecology Exchange (D 7.3; due July 2015)

Training and Education

- Designed and created Training and Education platform on Radioecology Exchange (see https://wiki.ceh.ac.uk/x/poGuD) (Population of platform WP6 output (D6.2)),

Conference dissemination

Promoted STAR at:

- NSFS Conference, Reykjavík, 22-25 August 2011
- The International Radioecology Conference, Hamilton 2011
- 12th International Conference of the Biogeochemistry of Trace Elements (ICOBTE) conference, Georgia 2013 (with associated special issue of J. Environmental Radioactivity)
- The International Radioecology Conference in Barcelona, 2014 - STAR (posters and presentations)
- Final dissemination event, Aix June 2015

7. **STATEMENT OF THE EUROPEAN ADDED VALUES OF THE ACCOMPLISHMENTS**:

The Radioecology Exchange

WHY: Prior to STAR, there was no single web site giving freely available, good quality information on environmental radioactivity. The only web sites created under European projects were project-specific.

WHAT: The creation of the Radioecology Exchange as the gateway to accessing on-line radioecological resources, is a major step forward in providing a wide range of information on environmental radioactivity in a single web site. The breadth of information is considerable. The structure of the site, using a wiki platform is a practical and effective means of creating a web site which allows STAR partners to easily contribute.

IMPACT. For a website to have an impact it has to include useful information, to be frequently updated, and to be well presented with a simple structure so users do not have to click too many links etc. It has taken about 3 years for us to accumulate and present enough good material to be able to advertise and inform the wider community about the site. Since then, the use of the site and its visibility has greatly increased such that it has commonly 100 unique visits per day. We firmly believe this will increase further given the enhanced effort to improve the site prior to the dissemination event and the end of the project. One key impact of the site is that it provides authoritative information on issues which are of current interest, such as Fukushima – a highlight being the Fukushima iResearch page – and much underpinning information on a wide range of relevant topics.

SUSTAINABILITY Because the radioecology exchange is built on a wiki platform it allows contribution from anyone registered to edit the site and as such it is potentially much more self-sustaining than web sites built on conventional platforms. The Radioecology Exchange will continue to be enhanced during COMET. Furthermore, STAR (and COMET) partners and the ALLIANCE have discussed approaches to the sustainability of the web site with other EC platforms. The ALLIANCE has also formed a working group to consider the sustainability of all STAR outputs (including the Radioecology Exchange) after the COMET project finishes.

Data transparency

WHY – Data needs to be maintained in a form which it is available in a sustainable format with good quality meta data. There is EC requirement to spatial make data available within the INSPIRE directive. Often, radioecological information is compiled at international level in a manner which makes it difficult to identify the underpinning data. To quote from a PhD student on the Radioecology Exchange - “Lack of access to data can be a problem. Sometimes ICRP, IAEA, UNSCEAR report different data for one issue”.

WHAT – Data held by STAR partners has been made more visible and accessible and some INSPIRE compliant data has now been added (more will be made available in the near future). STAR has provided guidance on how to curate and make data available in meetings and at an international “making data available” STAR workshop. Examples of enhancing the availability and transparency are being taken forward in STAR for major international data sets, including the animal product transfer parameter values, biological half-life data for wildlife and soil and freshwater partition coefficients (Kd) in co-operation with the IAEA MODARIA programme.

IMPACT – The transparency and provenance of data derived and collated within EC projects will be greatly enhanced and made more accessible to the wider community. The

approaches developed within STAR are leading the community at international level via the interaction with IAEA MODARIA programme where STAR partners chair four of the working groups. Databases made available have been used within STAR refereed publications, and have been particularly useful in identifying independent data to validate models – which is a particularly problem for many modellers. Access to data to validate models developed in the EC and elsewhere will improve model credibility.

SUSTAINABILITY – Improving current practices of data curation, availability and transparency makes international data sets transferable, so it is not necessary to reinvent the wheel. It will greatly facilitate more frequent updates at international level of the key collations of radioecological parameter values. Sustainability is an overall aim of good data curation.

Social media

WHY Prior to STAR there was no previous active social media site for radioecology.

WHAT The radioecology exchange has a frequently updated blog. STAR has also set up Twitter and Facebook accounts. We are at an early stage of enhancing these activities but think they will now expand rapidly.

IMPACT – The blog on the Radioecology Exchange is frequently updated by members of the STAR consortium and so reflects recent news; it is also available on the STAR and COMET sites. We have received requests to advertise (e.g.) jobs and conferences from many organisations via the blog. Currently, there are >100 followers of the Twitter feed which we anticipate will grow with time. The Facebook account has almost 250 followers.

SUSTAINABILITY – Social media activity is becoming much more frequent and now involves radioecologists outside of STAR. Many people are now getting used to tweeting and retweeting information and many students have signed up to the feed. Other organisations are also following the account (e,g. STUK, IRSN, CEH, some UK universities and EUrays (European Radiation Research Association for Young Scientists))).

8. **LIST OF PUBLISHED PAPERS**:

Hinton T., Brechignac F., Howard B.J., Liland A., Walker S., Yankovich T. 2014. Environmental radioactivity: legacy sites, Chernobyl and Fukushima (Editors) J. Environ. Radioact. 131, 1-3. http://dx.doi.org/10.1016/j.jenvrad.2013.12.002

Barnett C.L., Beresford N.A., Patel S., Wells C., Howard B.J., Mora J.C., Real A., Beaugelin-Seiller K., Gilbin R., Hinton T., Vesterbacka P., Muikku M., Outola I., Skuterud L., Ytre-Eide M.A., Bradshaw C., Stark K., Jaeschke B., Oughton D., Skipperud L., Vandenhove H., Vanhoudt N., Willrodt C., Steiner M. 2014. The Radioecology Exchange 3th International

Conference on Radioecology & Environmental Radioactivity. Barcelona, Spain, 7-12 September 2014.

https://intranet.pacifico-meetings.com/amsysweb/publicacionOnline.jsf?id=146

4.2 Annex 2. List of STAR publications

Related to WP2, 6 and 7

1. Hinton T., Brechignac F., Howard B.J., Liland A., Walker S., Yankovich T. 2014. Environmental radioactivity: legacy sites, Chernobyl and Fukushima (Editors) *Journal of Environmental Radioactivity* 131: 1-3.
2. Hinton T.G., Garnier-Laplace J., Vandenhove H., Dowdall M., Adam-Guillermin C., Alonzo F., Barnett C., Beaugelin-Seiller K., Beresford N.A., Bradshaw C., Brown J., Eyrolle F., Février L., Gariel J.C., Gilbin R., Hertel-Aas T., Horemans N., Howard B.J., Ikaheimonen T., Mora C., Oughton D., Real A., Salbu B., Simon-Cornu M., Steiner M., Sweeck L., Vives i Batlle J. 2013. Una invitacion para contribuir a la agenda estrategica de investigacion en radioecologia. *Radioproteccion* 74: 48-61.
3. Hinton T.G., Garnier-Laplace J., Vandenhove H., Dowdall M., Adam-Guillermin C., Alonzo F., Barnett C., Beaugelin-Seiller K., Beresford N.A., Bradshaw C., Brown J., Eyrolle F., Février L., Gariel J.-C., Gilbin R., Hertel-Aas T., Horemans N., Howard B.J., Ikäheimonen T., Mora J.C., Oughton D., Real A., Salbu B., Simon-Cornu M., Steiner M., Sweeck L., Vives i Batlle J. 2013. An invitation to contribute to a strategic research agenda in radioecology. *Journal of Environmental Radioactivity* 115: 73-82.
4. Oughton D.H., Howard B.J. 2012.The social and ethical challenges of radiation risk management. *Ethics, Policy & environment* 15 (1): 71-76.

Related to WP3

5. Beresford, N.A., Beaugelin-Seiller, K., Burgos, J., Cujic, M., Fesenko, S., Kryshev, A., Pachal, N., Real, A., Su, B.S., Tagami, K., Vives i Batlle, J., Vives-Lynch, S., Wells, C., Wood, M.D. Radionuclide biological half-life values for terrestrial and aquatic wildlife. *Journal of Environmental Radioactivity* In press.
6. Beresford N.A., Wood M.D., Vives i Battle J., Yankovich T.L., Bradshaw C., Willey N. 2015. Making the most of what we have: application of extrapolation approaches in radioecological wildlife transfer models. *Journal of Environmental Radioactivity* available on line doi:10.1016/j.jenvrad.2015.03.022 [Open access]
7. Hinton T.G, Byrne M.E., Webster S., Beasley J.C. 2015. Quantifying the spatial and temporal variation in dose from external exposure to radiation: a new tool for use on free-ranging wildlife. *Journal of Environmental Radioactivity* 145: 58-65.
8. Liland A. Modeling of radionuclide distribution in contaminated nuclear and NORM sites. In: Leo van Velzen (Ed.). *Environmental Remediation and Restoration at Contaminated Nuclear and NORM Sites*, pp. 115-142. Woodhead Publishing Series in Energy: Number 71, Oxford, UK, February 2015. ISBN: 978-1-78242-231-0 (print), 978-1-78242-238-9 (online)

9. Beresford N.A., Wood M.D. 2014. A new simplified allometric approach for predicting the biological half-life of radionuclides in reptiles. *Journal of Environmental Radioactivity* 138: 116-121
10. Brown J.E., Hosseini A., Dowdall M. 2014. On the application of an environmental radiological assessment system to an anthropomorphic surrogate. *Integrated environmental assessment and management* 10 (1), 125-132.
11. Chaplow J.S., Beresford N.A., Barnett C.L. 2014. Post Chernobyl surveys of radiocaesium in soil, vegetation, wildlife and fungi in Great Britain. *Earth Syst. Sci. Data Discuss.* 7, 693-711.
12. Beresford N.A., Vives i Batlle J. 2013. Estimating the biological half-life for radionuclides in homoeothermic vertebrates: a simplified allometric approach. *Radiation and Environmental Biophysics* 52: 505-511.
13. Beresford N.A., Yankovich T.L., Wood M.D., Fesenko S., Andersson P., Muikku M., Willey N.J. 2013. A new approach to predicting environmental transfer of radionuclides to wildlife: A demonstration for freshwater fish and caesium. *Science of The Total Environment* 463–464: 284-292.
14. Brown J.E., Beresford N.A., Hosseini A. 2013. Approaches to providing missing transfer parameter values in the ERICA Tool – How well do they work? *Journal of Environmental Radioactivity* 126: 399-411
15. Fisher N.S., Beaugelin-Seiller K., Hinton T.G., Baumann Z., Madigan D.J., Garnier-Laplace J. 2013. Evaluation of radiation doses and associated risk from the Fukushima nuclear accident to marine biota and human consumers of seafood. *Proceedings of the National Academy of Sciences of the United States of America* 110 (26): 10670-10675.
16. Hosseini A., Stenberg K., Avila R., Beresford N.A., Brown J.E. 2013. Application of the Bayesian approach for derivation of PDFs for concentration ratio values. *Journal of Environmental Radioactivity* 126: 376-387
17. Howard B.J., Wells C. Beresford N.A., Copplestone D. 2013. Exploring methods to prioritise concentration ratios when estimating weighted absorbed dose rates to terrestrial Reference Animals and Plants. *Journal of Environmental Radioactivity* 126: 326-337
18. Howard B.J. 2013. A new IAEA handbook quantifying the transfer of radionuclides to wildlife for assessment tools. *Journal of Environmental Radioactivity* 126: 284-287
19. Psaltaki M., Brown J.E., Howard B.J. 2013. TRS Cs CRwo-water values for the marine environment: analysis, applications and comparisons. *Journal of Environmental Radioactivity* 126: 367-375
20. Wood M.D., Beresford N.A., Howard B.J., Copplestone D. 2013. Evaluating summarised radionuclide concentration ratio datasets for wildlife. *Journal of Environmental Radioactivity* 126: 314-325
21. Brown J.E., Hosseini A., Seymour C. 2011. Modelling transfer to animals accounting for trans-generational factors. *Radioprotection* 46(6):S509–S514.

Related to WP4

22. Horemans N., Van Hees M., Saenen E., Van Hoeck A., Smolders V., Blust R., Vandenhove H. 2015. Influence of nutrient medium composition and growth related endpoints on uranium toxicity in Lemna minor. *Journal of Environmental Radioactivity* in press, available on line http://dx.doi.org/10.1016/j.jenvrad.2015.06.024
23. Horemans N., Van Hees M., Van Hoeck A., Saenen E., De Meutter T., Nauts R., Blust R., Vandenhove H. 2015. Uranium and cadmium provoke different oxidative stress responses in *Lemna minor*. *Plant Biology* 17, 91-100.
24. Lofts S., Février L., Horemans N., Gilbin R., Bruggeman C., Vandenhove H. 2015. Assessment of co–contaminant effects on uranium and thorium speciation in freshwater using geochemical modelling. *Journal of Environmental Radioactivity*, 149: 99-109.
25. Margerit A., Lecomte-Pradines C., Svendsen C., Frelon S., Gomez E., Gilbin R. 2015. Nested interactions in the combined toxicity of uranium and cadmium to the nematode *Caenorhabditis elegans*. *Ecotoxicology and Environmental Safety* 118: 139–148.
26. Song Y., Salbu B., Teien H.-C., Heier L.S., Rosseland B.O., Høgåsen, T., Tollefsen K.E. 2014.Hepatic transcriptomic profiling reveals early toxicological mechanisms of uranium in Atlantic salmon (*Salmo salar*). *BMC genomics* 15 (1): 694.
27. Song Y., Salbu B., Teien H.-C., Heier L.S., Rosseland B.O., Tollefsen K.E. 2014. Dose-dependent hepatic transcriptional responses in Atlantic salmon (*Salmo salar*) exposed to sublethal doses of gamma radiation. *Aquatic Toxicology* 156: 52–64.

Related to WP5

28. Biermans G., Horemans N., Vanhoudt N., Vandenhove H., Saenen E., Van Hees M., Wannijn J., Vangronsveld J., Cuypers A. 2015. Biological effects of α-radiation exposure by 241Am in Arabidopsis thaliana seedlings are determined both by dose rate and 241Am distribution. *Journal of Environmental Radioactivity*, 149: 51-63.
29. Biermans G., Horemans N., Vanhoudt N., Vandenhove H., Saenen E., Van Hees M., Wannijn J., Vangronsveld J., Cuypers A. 2015. Arabidopsis thaliana seedlings show an age-dependent response on growth and DNA repair after exposure to chronic γ-radiation. *Environmental and Experimental Botany* 109: 122-130.
30. Parisot F., Bourdineau J.-P., Plaire D., Adam-Guillermin C., Alonzo F. 2015. DNA alterations and effects on growth and reproduction in *Daphnia magna* during chronic exposure to gamma radiation over three successive generations. *Aquatic Toxicology* 163: 27–36.
31. Vanhoudt N., Horemans N., Wannijn J., Nauts R., Van Hees M., Vandenhove H. 2014. Primary stress responses in Arabidopsis thaliana exposed to gamma radiation. *Journal of Environmental Radioactivity* 129: 1-6.

32. Lance E., Alonzo F., Garcia-Sanchez L., Beaugelin-Seiller K., Garnier-Laplace J. 2012. Modelling population-level consequences of chronic external gamma irradiation in aquatic invertebrates under laboratory conditions. *Science of the Total Environment* 429: 206-214.