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Report on development of innovative mechanisms for joint programming and implementation for future research in radioecology

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1. Introduction

The aim of this deliverable is to describe mechanisms for joint programming and implementation in the field of radioecology developed during the COMET project. This includes the development of mechanisms to prioritise research areas and develop an overall integrated research implementation plan.

One of the initial activities within COMET was identifying 'Competitive Call' topics, setting up an evaluation process and selecting projects (Vandenhove et al., 2013). In doing this, we collaborated with the EC-OPERRA[1] project. This call priority identification and selection is now imbedded within the EJP EC-CONCERT project[2] activities.).

Within this deliverable we concentrate on the tools developed by COMET and supported by the European Radioecology Alliance (ALLIANCE[3]), to foster research prioritisation, integration and sustainability of radioecological research within Europe.

Through topical 'roadmap' working groups we have developed mechanisms of joint programming and implementation following the establishment of criteria and processes for prioritisation of research. A sustainable implementation processes has been initiated with the ALLIANCE and in close interaction with the broader radiation protection sciences as represented by OPERRA and CONCERT.

From the perspective of COMET and the ALLIANCE the subject of the research prioritisation and implementation is the Strategic Research Agenda (SRA) for radioecology in Europe[4]. We have developed mechanisms to prioritise and implement (and integrate) research priorities from the ALLIANCE SRA. In this deliverable we discuss: the process to come to a selected set of criteria for research prioritisation (chapter 2); the roadmap working groups developed under COMET, with the support of the ALLIANCE (chapter 3); and the Observatory sites as tools for integrated integration (chapter 4).

At the European level there is enhanced integration of the radiation protection research area through collaboration within the MENAE community (MELODI[5] (low-dose research), EURDOS[6] (radiation dosimetry), NERIS[7] (emergency), ALLIANCE (radioecology), EURAMED[8] (Medical applications)),. We are therefore on the path to establishing, common SRAs and roadmaps (chapter 5) and we have developed integrated radiation protection calls (chapter 6). This process began under OPERRA and has continued under CONCERT. Chapter 7 discusses the future for Radioecology within the European radiation protection landscape.

1 OPERRA: Open Project for the European Radiation Research Area, http://www.melodi-online.eu/operra.html
2 CONCERT: European Joint Programme for the Integration of Radiation Protection Research, http://www.concert-h2020.eu
3 http://www.er-alliance.eu/
4 SRA available at **www.radioecology-exchange.org**
5 MELODI: Multidisciplinary European Low Dose Initiative, http://www.melodi-online.eu
6 EURADOS: European Dosimetry Group, http://www.eurados.org
7 NERIS: European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery, http://www.eu-neris.net
8 EURAMED – The European alliance for medical radiation protection research, http://www.eibir.org/scientific-activities/joint-initiatives/european-alliance-for-medical-radiation-protection-research-euramed/

2. Criteria for research prioritization and roadmap development

In preparation of the COMET call, a first attempt was made to describe how to implement a number of research priorities listed in the strategic research agenda (SRA) which is based on 3 challenges and 15 associated research lines (Deliverable 2.1, Vandenhove et al., 2013). The outlines of key-research activities described in D2.1 were approved by various organizations after the integration of comments from 50 individuals from 24 institutes (COMET and ALLIANCE partners, COMET Steering Committee, NERIS and MELODI community). D2.1 was the result of the activities of a STAR[9]-COMET working group; it was discussed within the COMET Steering Committee (7 Oct 2013) which included representatives of the other radiation protection research platforms (MELODI, NERIS), and was endorsed by the ALLIANCE and as such constituted a helpful document to structure and enhance interactions between the ALLIANCE, NERIS, MELODI and EURADOS.

Two main comments on D2.1 were given by the COMET Steering Committee prior to the first annual COMET meeting: (i) to include among the 5-year priority activities also SRA Challenge 3-linked research priorities; and, (ii) in order to select key research priorities from the list identified in D2.1, a 5-year research strategy needed to be formulated. The strategy selected would also dictate in part criteria for research prioritization. At the COMET annual meeting in May 2014, a proposal for a 5-year strategy and associated criteria was discussed and a final strategy and criteria were proposed.

2.1. Towards a strategy for establishing a 5-year roadmap and implementation plan

In our development of a final strategy for establishing a 5-year roadmap and implementation plan, the overall strategic objective was articulated: *Underpinning science for an enhanced basis for fit-for-purpose human and environmental impact assessment by mechanistic modelling, improved parametrization and improved databases.*

The scoping was set as follows:

- The focus should extend *from basic science (mechanistic understanding) to application* to improve radiation protection and communication with society.
- Research proposed should *interlink the different Challenges* presented in the Radioecology SRA. Aspects from Challenge 3 should always be considered.
- Prioritising research topics of radioecology within the roadmap also to areas relevant for post-emergency management, low-dose effect and dosimetry research, to provide a *powerful catalyst to further develop collaboration between the four platforms* of radiation protection, ALLIANCE, NERIS, MELODI and EURADOS.

The overall strategy was translated to an approach and expected outcome for the 3 Challenges of the SRA:

[9] Network of Excellence STAR (Strategy for Allied Radioecology) funded by the 7FP of the EC.

- For Challenge 1
    - Approach: Improve human and environmental dose and impact assessment by mechanistic/process-based modelling of environmental transfer and exposure in the biosphere
    - Expected outcome: Fit-for-purpose environmental models to support human and wildlife impact assessment and risk management.
- For Challenge 2
    - Approach: Unravel causes and mechanisms of radiation induced effects in wildlife from molecular to individual levels up to populations.
    - Expected outcome: Knowing causes of biological effects to detect early damages and to protect populations.
- For Challenge 3
    - Approach: Improve risk characterisation by better quantification of uncertainty and variability of exposure and effects.
    - Expected outcome: An integrated approach to enhanced risk characterisation and communication (connecting science, economy & society)

2.2 Criteria for Research Prioritization

It is recognized that too many research lines were covered in the "first phase" roadmap highlighted in D2.1. It was consequently decided that the prioritising process should be strengthened. The prioritisation process is dependent on the criteria which are used for the selection of the research lines identified in the SRA. Those criteria in turn, should emerge from the overall strategy.

The overall objective of the 5-year research activities is, as stated above, to advance in underpinning science for an enhanced basis for fit-for-purpose human and environmental impact assessment by mechanistic modelling, improved parametrization and improved databases.

A list of research prioritisation criteria was established during the ALLIANCE-STAR SRA stakeholder consultation meeting in November 2012 and amended following discussions during the COMET kick-off meeting in August 2013. This resultant list of 8 criteria (page 34 of D2.1) was further reduced at the COMET first Annual meeting in May 2014 and the four following criteria were retained: IMPACT, ACHIEVABLE, RELEVANCE AND PUBLIC PERCEPTION, GOOD SCIENCE (Table 1). Secondary (explanatory) criteria were developed which can be used as guidance when applying the primary criteria.

Table 1: Final List of Criteria for Research Prioritization

Broad Area	Specific criterion	Comments
Impact	*Substantial enhancement of knowledge*	Required to give confidence to stakeholders and provide an improved capability giving greater confidence in decision making.
	Addresses major unresolved issues relevant to radiological protection	Ensures that the overall enhancement of knowledge is directed to the specific requirements of the radiological protection community.
	Practical applicability	Results can be used directly or readily adapted for use by legislators, regulators, operators and other interested parties
	Public relevance	Seen to be addressing issues of public interest or concern.
Achievability	*Realistic on a five-year timescale*	Or at least feasible to undertake in stages, so that well-defined interim goals can be achieved and demonstrated within five years.
	Sufficient guaranteed capacity	Sufficient internal resources within the ALLIANCE to deliver a useful product even in the absence of external funding.
	Adequate basis in current knowledge and experience	Builds on existing knowledge and makes use of experience and facilities that are available within the research community.
	Appropriate level of risk of failure	Suitable balance between high risk and low risk components, i.e. there is a need to ensure that some useful outcome is delivered, but this should not stifle the need to undertake speculative work that could lead to a high return if it is successful.
Relevance & public perception	*High relevance for protection of humans*	Implies a focus on the radionuclides and pathways that contribute most to doses to humans in a variety of assessment contexts.
	High relevance for the protection of wildlife	Includes consideration of biodiversity, ecosystem performance and health, sustainability and protection of endangered species. Again, implies a focus on key radionuclides and pathways in a variety of assessment contexts.
	Relevant to research initiatives in areas outside radioecology	Include prioritise of relevance to the low doses, emergency planning and preparedness and dosimetry fields.
	Addresses major unresolved issues relevant to radiological protection	Duplicates the corresponding item under impact, so could be deleted in one or the other instance.
	Important and relevant	Are the results to be obtained of importance from a public perspective (irrespective of their significance for radiological protection? Are results of relevance to an issue of great public interest. Will results be of direct relevance to members of the public in enhancing their understanding of a given situation and informing their decision making.
	Convincing	Has provision been made to demonstrate why a member of the public should place credence in the results to be obtained, e.g. by explaining the background to the work in appropriate language and showing how it fits within a broader body of scientific knowledge?
Good science	*Logical development*	Builds on existing understanding and addresses a generally recognised deficiency in that understanding (e.g. due to lack of data or an appropriate conceptual model of the processes and mechanisms of relevance).
	Hypothesis driven	The research should be targeted to support or refute one or more hypotheses.
	Innovative	In so far as innovation enhances our ability to answer the key questions posed by the research topic.

A more realistic roadmap in terms of time and scoping was then to be built and implemented in collaboration with the ALLIANCE. The time frame of the roadmap was kept at 5 years. The scope of core-interest will partially be research needs shared with the other research platforms.

In turn, the ALLIANCE organised a workshop (29-30 April 2014) to identify the on-going research activities and present fields of excellence of each ALLIANCE member. This constituted part of the basic information to identify groups of interest per challenge/research line of the SRA. ALLIANCE members were asked to show their interests and expertise in the priority research areas in D2.1 identified for the COMET call and the initial research activities developed in for WP3 of COMET D3.1 (Liland et al., 2013).

3. The COMET/ALLIANCE roadmaps: status and action plan

3.1 Establishing thematic priority roadmap working groups

Templates were developed for initiation of roadmap working groups and for further development of selected roadmap themes.

The 'roadmap initiation template' asked for input on title/acronym, leadership and/or initiating partner(s), topical area, broad bbjectives, justification based on answers to the criteria for prioritisation of research, question(s) to be addressed, related challenge(s) and research line(s) in the Radioecology SRA, potential collaborators.

These roadmap initiation templates were discussed at the level of the COMET Management board and with the ALLIANCE members. Topics that were considered relevant based on the criteria specified and for which there was enough critical mass to perform the activity were selected and the roadmap WGs were asked to further develop the priority research topics in a second template. This second template began to identify the intended inputs of the partners together with expected outcomes and an estimated duration of the WG to accomplish its plan.

The latter implied (1) Planned research activities and time scale: tasks, responsibilities, participants, use of observatory sites, use of large scale facilities, milestones, deliverables, resources committed by partners (estimated man.months, indoor funds), requested funds and targeted calls (EC Call, other calls); (2) Major elements of the communication plan (workshops, publications, guidance documents…); (3) links with other activities identified at the national and the international levels; (4) expected problems, gaps/lack of knowledge, etc. that might prevent the accomplishment of the research.

The roadmap working groups are in principle critical mass for progressing our science on complex issues which require collaboration, for fostering integration and contribute to European Joint Programming. The intention is that by the shared effort of the participating organisations advances in science can be made, partially or largely based on own research funds. Progress will only be possible when the participating institutes aline their research priorities to the priorities of the global European radioecology research community as identified in the SRA and endorsed by stakeholders.

There has been some advancement in the development of the roadmaps in terms of work content, tasks, milestones, deliverables etc. but effective research execution was rather limited in many cases. In reality (and perhaps not unsurprisingly) if there is no external funding it is difficult to have the thematic roadmap working groups effectively working together to the extent hoped for. However, the

WGs have provided justification for the CONCERT EJP calls and also given the responders to these call a basis on which to frame their intended activities.

Below we present the thematic roadmap working groups' objective and major achievements. In Annex 1, the full description of the thematic roadmap working groups' is given.

3.2. A short description of the thematic roadmap working groups

3.2.1. Naturally-Occurring Radioactive Materials (NORM)

The main issue in view of NORM-impacted sites is how such sites, e.g. radium contaminated sites, uranium liabilities, sites exploited for the mining of metals associated with NORM and wastes arising from industries processing or generating other kinds of NORM, are assessed and regulated. In view of the implementation of the new Basic Safety Standards (BSS), the regulations apply to the management and clean-up of existing sites as well as to the licensing of future discharges and large quantities of NORM waste. This necessitates a better understanding of key routes involved in the migration and bioavailability of radionuclides at NORM sites, i.e. to develop (i) sampling strategies to characterize NORM-contaminated sites, (ii) the practical use of hydrogeological and hydrogeochemical mechanistic modelling together with a process-based understanding of radionuclide migration in abiotic and biologically influenced environments, radionuclide transfer into biota and finally into the human food chain, and (iii) projective modelling for existing sites as well as generic modelling for licensing procedures on timescales from years to millennia. Research in these directions will support the development of advanced generic radioecological models with a lower degree of conservatism, thus avoiding unnecessary restrictions in licensing procedures whilst ensuring protections of humans and the environment. Due to the complexity of NORM sites, which are characterized, for instance, by complex mixtures of different chemicals and minerals as well as disequilibria in radionuclide decay chains, challenges arise not only from the lack of comprehensive scientific data, but also from existing model concepts themselves, which do not adequately describe the interplay between simultaneously occurring processes at a NORM site. Therefore, a promising strategy is to reduce modelling uncertainties by identifying and parametrizing the key processes that influence the radionuclide behaviour and to transfer this knowledge into a mechanistic model sufficiently complex to describe the radionuclide behaviour in the environment, however, simultaneously simple enough to be practical and applicable to different NORM sites. In view of potential hazards associated with the radioactive source term of NORM sites related to former, current or future human activities, as well as the need for developing preventive methods at different stages of a technological process in a NORM industry, this is an important task.

WG group NORM currently is composed of 18 organisations from 10 European countries. Almost all groups contributed to the preparation of the current version of the WG NORM roadmap document. It contributes to Challenge 1 of the radioecology Strategic Research Agenda (SRA), research lines 1 to 3, by (i) identification and parameterization of key processes relevant for the environmental transfer of naturally occurring radionuclides and the resultant exposure of humans and wildlife, (ii) acquiring data necessary for the parameterization of key processes controlling the behaviour of radionuclides in the environment, and (iii) by improving existing models or developing parametric models linking observed accumulation, mobility (K_d), and transfer (TF and fluxes) with environmental parameters and processes

to enable spatial and temporal predictions. The resulting knowledge is needed for a more reliable description and prediction of the behaviour of natural radionuclides in environmental compartments, including dynamic processes. This WG will generate new knowledge necessary to assess NORM resulting exposures of both humans and non-human populations with substantially reduced uncertainty.

Achievements

- A roadmap was developed that focusses on important priorities within NORM related research. A strategy was set-up to deal with these issues in the coming years. The elaboration of the roadmap document allowed the integration of the research performed by the different partners and contributed to an increasing collaboration between the partners.
- Members of WG NORM contribute to the COMET position paper which is currently put together by Boguslaw Michalik.
- A one day discussion meeting of WG NORM was organized by the leaders of the WG (26th January, 2016) in Munich. The purpose was to (1.) present a short summary of NORM sites that are currently under consideration by the group members, (2.) discuss the present status of transport models used for the impact assessment of NORM radionuclides (used transport models, key concepts, input for transport codes), (3.) discuss future needs for research in respect to input parameters for existing transport models, (4.) introduce the regulator's perceptions and needs (Finnish and German point of view) as well as to recent IAEA activities, and (5.) discuss a possible proposal/contribution of WG NORM for the 1st CONCERT call.
- WG NORM was presented by Maarit Muikku during the NordicNORM 2015 Workshop in Helsinki, Finland.
- The number of WG NORM members has increased to 18 in the last year indicating the great interest in NORM studies in Europe
- Initial research activities were already started and a joint research proposal was submitted within the first CONCERT call.

Future steps

- If there is no common funding it will be difficult to execute the work as proposed in the roadmap. However, if possible, institutes can perform research within the scope of the roadmap, maybe on a bilateral level with national funding or with funding of small research projects by the ALLIANCE.
- The EC-project TERRITORIES[10], in which a number of the roadmap WG members are involved, considered NORM-related issues and develops research at one of the ALLIANCE Observatory Sites.
- It is suggested to maintain the network and to continue with the proposed work as outlined above and being ready for international calls.

[10] TERRITORIES = To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations http://territories.eu

3.2.2 Human Food Chain

The Working Group activities aim to improve radioecological models used in (decision support systems) DSS in Europe, including the inclusion of agricultural practice/production and dietary habit data for different regions. This should lead to improved recommendations of remedial actions and their consequences. In part some of the activities of the WG were initiated, but largely not carried forward, in earlier EC projects (e.g. SAVE, STRATEGY[11]). The WG will learn from the Fukushima and Chernobyl accidents.

The revised ICRP Recommendations state that model predictions should be able to assess the first year dose to humans from all exposure pathways. One important pathway over this time is through the human food chain. The Terrestrial Food Chain and Dose Module (FDMT) is used in Europe within both the ARGOS and RODOS DSS to predict doses from ingestion. One of the deficiencies of the FDMT as currently implemented, is the fact that most default parameters (based on German values) may not be appropriate for other regions in Europe.

The focus of the working group over the first 5 years will be the consideration of post-accidental situations in both the short and longer-term. As such the WG will try to learn from studies in Japan following the Fukushima accident (i.e. were there unexpected pathways, how well did models parameterised for European systems work, what parameters/information were lacking in trying to respond to contaminated foodstuffs) and also put these into context with lessons learnt in Europe following the Chernobyl accident.

The R&D is organised around four major tasks:

- Task 1 Mechanistic and dynamic transfer studies
- Task 2 Development of regional parameters
- Task 3 Remediation measures
- Task 4 Improvement of models and Bayesian statistics

Where relevant radionuclides associated with, for instance, waste disposal will also be considered. The WG will consider all terrestrial (focussing on agricultural) and freshwater foodstuffs. The WG will not consider NORM radionuclides, nor food products from forest or marine ecosystems as these areas all have dedicated WGs.

Our objectives will be achieved through a combination of experimental/field studies and modelling (sensitivity analyses, testing and improvement). Key strength of the ALLIANCE in being able to achieve this are our wide-ranging expertise, facilities, databases and experience. A number of research topics will be initiated through PhD studentship and our work plan will consequently also contribute to future capacity building. Where appropriate we will align our activities with those of the IAEAs MODARIA II to maximise resources, relevance and impact.

Some of the activities presented in Annex 1 are already on-going/planned in individual member institutes (other key activities are not on-going nor has funding been identified to achieve them), a challenge for the ALLIANCE will be to co-ordinate research activities in a focussed manner and to broaden participation in key research areas.

[11] See http://www.radioecology-exchange.org/content/euratom-project-outputs

Achievements

Within the COMET project one of the initial research activities was focused on the human food chain and this has made some progress against the Roadmap activities as outlined above as follows:

- A Bayesian meta-analysis of key parameters of the foliar pathway (interception in dry and wet conditions, weathering) and propagation of these (and other) parametric uncertainties in various post-accidental scenarios has been conducted.
- The long-term dynamics of ^{99}Tc, Pu and Am transfer from different soils to crops has been studied in the Chernobyl Exclusion Zone (Levchuk et al. 2015).
- The long-term behaviour ^{137}Cs and ^{90}Sr in human food chains has been investigated for peat soils in the Ukraine (Kashparov et al. 2015; Maloshtan et al. 2015a,b; 2016). Laboratory studies have furthermore obtained parameters for the dynamics of the ^{137}Cs root uptake by grass growing on peat-bog (Histosols) soils.
- Derivation of regional parameters (e.g. growing season, harvest times, seasonal development of leaf area indices, animal feeding practices and human diets) for the Mediterranean and Nordic regions (Thørring et al. 2016).

The HARMONE[12] project funded via the OPERRA project has directly addressed aspects of Task 2 of the Roadmap. HARMONE identified those parameters within radioecological models used in decision support systems which may vary regionally (Staudt 2016a). If then defined 'radioecological regions' suggesting region specific parameters were possible (Staudt 2016b). HARMONE also considered the need for site specific data versus default parameters in the RODOS foodchain model to give robust human dose assessments in the event of an emergency.

Various national initiatives have also made progress against the Roadmap activities:

- It has been demonstrated that inter-varietal variation in the uptake of Cs and Sr is such that it represents a feasible countermeasure to reduce the transfer of these radionuclides to humans from animal products (via forage grass) and crop plants (Penrose et al. 2016; submitted 2017) [lead ALLIANCE organisation: NERC-CEH]
- Transfer parameters for goat and cow milk have been reviewed providing parameters for some additional elements (Howard et al., 2016; 2017) [lead ALLIANCE organisation: NERC-CEH]
- A generic model to describe the soil K_d of Cs has been developed which takes into account ionic strength and solution pH; the model considers frayed edge and planar sites of clays. [lead ALLIANCE organisation: IRSN]
- Studies have been conducted to investigate the use of Diffusive Gradient in Thin Film (DGT) and RHIZOtest to predict plant uptake [lead ALLIANCE organisation: IRSN]
- Studies have begun investigating the role of K transporters in Cs transfer to plants. [lead ALLIANCE organisation: IRSN]
- Studies of the role of humic acid-like compounds during the biodegradation of ^{137}Cs contaminated plant biomass have provided results which could usefully contribute to the management of contaminated biomass. [lead ALLIANCE organisation: IST]

[12] HARMONE - Harmonising Modelling Strategies of European Decission Support Systems for Nuclear Emergencies : https://www.helmholtz-muenchen.de/en/iss/research/work-groups/integrative-modelling/projects/operra-harmone/index.html

Future steps

Funding through the first CONCERT EJP call will ensure that progress continues to be made against the objectives of this roadmap. Most especially, the CONFIDENCE13 project has a work package (WP) on reducing uncertainties in food chain modelling (all WP members are ALLIANCE members). The WP has three tasks which directly address the roadmap and Radioecology SRA:

- Improving (human food chain) models
- Can process based models reduce uncertainties?
- Including 'hot particles' in radioecological models

The WP will largely address Task 1 and to a lesser extent Task 2 of the Roadmap. CONFIDENCE has also provided a focus for joint PhD studentships two having been proposed. One of these (NERC-CEH, SCK•CEN and Nottingham University) has not been funded and will be resubmitted; the other (University of Extremadura and NERC-CEH) was successful. Collaborative PhD-studentships obviously present opportunities for progressing the Roadmap in the future.

Funded through the same call, the TERRITORIES project is considering existing exposure situations for both humans and wildlife. None of the work packages directly consider the human food chain. However, there will be consideration of the dietary exposure route and measures to reduce exposure via this route.

One of the projects funded under the first ALLIANCE call for small collaborative projects is focused on the human food chain roadmap and will evaluate the validity of the increasing use of stable elements as proxies for radionuclides in defining transfer parameters for radioecological models (focusing on Cs and Sr). This has also provided a mechanism of initiating activities with 'new' institutes not within the core teams of the STAR and COMET projects. Subsequent ALLIANCE calls may provide a further mechanism for progressing the Roadmap accepting that the funding level of these projects is low.

3.2.3. Marine radioecology

The Fukushima Dai-ichi NPP accident in 2011 has refocused the vision for marine radioecology by highlighting the importance of post-accidental consequences for the marine environment and the limited knowledge that we have in that area. It constituted the most important accidental release of artificial radionuclides to the oceans that has ever occurred. Contamination of every marine component (water, sediment and biota) has been observed. The understanding of contamination levels and radionuclide distributions in the environment, along with prediction of their future evolution requires analyses of detailed monitoring data and the use of modelling tools. In the aftermath of an accidental situation where radioisotopes in the different marine compartments have not equilibrated, time-dependent radioecological models of transfer are required. Such situations offer the opportunity to validate and improve models that are, or have the potential to be, included in decision support systems (DSS) for emergency situations. This post-accidental situation also shows the necessity to develop research on more realistic (and sophisticated) models taking into account trophic transfer

13 CONFIDENCE - COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs - https://portal.iket.kit.edu/CONFIDENCE

process related to pelagic or benthic organisms but also to develop alternative transfer models between dynamic FC and food chain model.

Three objectives/tasks have been identified.

Task 1: Marine dispersion modelling. The task is devoted to development and validation of tools to model marine radionuclide dispersion. It includes knowledge of activity levels in marine areas. Dissolved or particulate bound radionuclides are concerned in this task.

Task 2: Radioecological transfer in marine environment. This task includes modelling and experimental studies (to quantify transfer parameters or to study specific processes) to assess the transfer to biota and sediments

Task 3: Fukushima case study. This task aims to have a better understanding and estimation of the long-term behaviour and fate of radionuclides released from Fukushima station.

Achievements

The marine roadmap content, finalized in January 2016, provides a good synthesis of the various research issues for marine radioecology in Europe in the post-Fukushima era. This accident has refocused the vision for marine radioecology by highlighting the importance of post-accidental consequences for the marine environment and the limited knowledge and preparedness that we have in that area. Therefore, the roadmap was structured around three main tasks for what the different European partners proposed their own contribution: Marine dispersion modelling, radioecological transfers study and modelling, and Fukushima case study. These tasks deal with challenges 1 and 3 of the SRA. Mechanistic/process-based modelling of environmental transfer and exposure in the biosphere are improved/developed. A better quantification of uncertainty and variability of exposure is a common concern here.

During one year, progress and achievements have been done for each task mainly within the frame of existing national or European/International projects (COMET-FRAME, AMORAD[14], EFMARE[15], HARMONE, TREE[16], IAEA-MODARIA2), or with partners' funding for PhD research.

Each partner contributes to this roadmap with a limited number of people and funding, building knowledge blocks within one or different tasks. Main progresses ongoing at this time are:

- Improvement of dispersion models at local scales.
- Improvement of dynamic transfer models and dose calculations to marine organisms.
- Radioecological parameters (FC and Tb) evaluation using in-situ data.
- Research on the role of different vectors to contamination transfer through food web and investigations on trophic transfers.
- Development of a global database of marine kd values of the marine environment with investigation of factors influencing kd variability in the marine environment (this work is being carried out as part of the IAEA MODARIA II Program).

[14] http://www.irsn.fr/EN/Research/Research-organisation/Research-programmes/AMORAD/Pages/AMORAD-program.aspx
[15] http://www.nks.org/en/nks_reports/view_document.htm?id=111010213400466
[16] http://tree.ceh.ac.uk/

- Implementation of transfer to sediment in some operational models (DDAT at this time).
- Studies in Fukushima area to provide a good knowledge and understanding of the radioecological situation, including estimation of land inputs (rivers and underwater).

Future steps

There is a radiological assessment problem of determining the degree of readiness for a possible accident of a nuclear reactor in European waters, meaning that the work to improve dispersion and biological transfer models and provide better parameters for them must continue.

Marine radioecology scope is very large, behaviour and fate of radionuclides complicated to investigate due to the difficulty and the cost to get measurement data. There is a strong need to have more funded collaborative projects with the wider research community dealing with how other contaminants disperse and transfer to different parts of the environment

Marine radioecology is of cross-border importance (the sea does not stop at any manmade border), and thus it is wholly legitimate to instate European funding, thereby ensuring that a cross-border harmonised approach is adopted.

Moreover, research in marine radioecology appears not only as purely scientific but also of societal relevance. The attempt to approach socio-economic community has to go on.

3.2.4 Transgeneraltional effects and species radiosensitivity

The issue of biological effects of low doses of ionising radiation along with the 'hot question' from the public/media on the potential hereditary effects for both humans and wildlife is of major concern. This has been reinforced after the Fukushima accident, especially with respect to the quantification (and reduction if needed) of the magnitude of risk to individual (human) and population (human and biota) health when exposed at low doses/dose rates for multiple generations. This concerns both chronic exposure over several generations, and intermittent exposure (e.g. consequences of a short exposure in one generation to the others). The challenge is clearly to improve our understanding of the cascade of responses, from primary interactions of ionising radiation with biomolecules to adverse outcome for physiological functions, including reproduction, and ecosystem function.

Addressing the issue of biological consequences induced by low doses, we need to improve our knowledge on long term and transgenerational effects. This includes the study of genetic changes (mutations) but also the role of epigenetic mechanisms, both determining the adaptation ability of organisms. In particular, the role of epigenetics in genomic instability and inheritance in organisms/cells exposed to radiation/radionuclides and also in adaptation of organisms under conditions of a pressure selection must be better understood. In perfect complementarity, mutation rates and types are to be assessed and quantified in parallel. This will enable distinguishing between epigenetic and genetic induced changes.
The second topic of interest in this working group deals with differences of radiation sensitivity across species and phyla are poorly understood, but have important implications for understanding the overall effects of radiation and for radiation protection: sensitive species may require special attention in monitoring and radiation protection; and differences in sensitivity between species also lie behind

overall effects at higher levels (community, ecosystem), since interactions between species will be altered. Understanding the mechanisms of inter-species radiation sensitivity may also help us understand mechanisms behind intra-species variation.
The objectives/tasks of this thematic roadmap working group are the following:

Task 1 Biomarkers of transgenerational/adaptation effects: laboratory (and possibly field) studies will be undertaken to identify genes/proteins/epigenetic marks that are critically involved (i) in transgenerational effects or (ii) in radionuclide-resistance, and are prime candidates to identify transgenerational effects. The acquired data will be integrated in population dynamics models, allowing a comparison of protection thresholds for the individuals or the population levels.

Task 2 Radioadaptation: priming experiments will be performed by exposing organisms to a low dose; the effect of a subsequent exposure to the same or another stressor will provide knowledge in physiological adaptation within the same generation or over several generations. Transgeneration/adaptation mechanisms will also be studied in populations and ecosystems by characterizing effects of ionizing radiation on natural populations exposed in situ.

Task 3 Role of metabolism in transgenerational/adaptation effects: the metabolic activity of cells and organisms can provide a highly reproducible biological signature of radiation effects (studied in bacteria at HZD). This approach could be applied to other organisms and be directly used in a DEBtox model to infer on the possible role of metabolic activity in transgenerational effects.

Achievements

The partners of the WG are coming from different fields of radioecology as well as ecotoxicology with a great diversity on research topics as well as study organisms. This ensures the potential ground for future collaborative work and experience. Within the last year considerable progress was made within COMET WP4 by the involved partners on the possible contribution of epigenetic mechanisms to transgenerational effects. This resulted in the position paper and initiated the writing of the BIOMARKER project as main achievements. Facilitated through the WG additional (bilateral) collaboration has been set up like the involvement of partners in PhD guidance committees.

Main ongoing progresses at the moment are

- Establishment of the roadmap following e-mail discussion as well as some web-meetings
- Tasks 1 and 2 integrate within the framework of COMET WP4 Initial Research Action, dedicated to understanding the role of epigenetic mechanisms in transgenerational effects. The outcome of this is given in the COMET deliverable D4.2. The work within WP4 was dedicated labwork as well as field sampling campaigns in both Chernobyl and Fukushima.
- Additional efforts addressing the different tasks have been made within the partners own funded research and PhD projects.
- A position paper was written by a number of the WG group partners also as part of the outcome of the WP4 of COMET and will be submitted as a review and statement paper summer 2016.

- Task 1, 2 and 3 are now put together as a project proposal entitled BIOMARKERS (coordinated by Ch. Adam-Guillermin) for the 2nd CONCERT call. As budget for this call was limited not all topics or partners could be integrated within the project
- The outcome of the WG was presented as a poster on the COMET final event (25-27 april 2017, Bruges) and as a presentation on the ALLIANCE workshop (28 April, Bruges)

Future steps

The diversity of the partnering groups is being experienced as a positive mark but it also has the backside that each of the groups deals with their own studies. As such trying to link them through a WG and to put the research in the same direction is not experienced as easy. Further it is impossible to know whether the WG really facilitated the new or strengthened collaborations that were established in the last years. Especially as the WG has no budget or limited financial opportunities it remains questionable what the guiding role of the WG could be. However the topics of the effects WG are still very up front challenges within radioecology and can lead to high-utility and valid approaches needed to support radioecological protection and risk assessment such as the identification and validation of biomarkers for chronically exposed environmental relevant conditions. As these topics are so large it is seen as very valuable to unite the efforts of different partners. However, the group needs to become more active as a group. It might be an idea to reform the working group more to a forum or entry point (through the radioecological exchange website) that can help future interactions/collaborations rather. One face-to-face meeting each year with all members of the WG, also involving students, could also perhaps lead to synergism (e.g. summer school as organized during the STAR project in Chernobyl or in parallel of important conferences such as ICRER or SETAC meetings).

3.2.5 Atmospheric Dispersion and Transfer Processes

This roadmap working group was not initiated by COMET but by the ALLIANCE. Since after COMET all thematic roadmap working groups will be fully absorbed by the ALLIANCE, we also present this thematic roadmap working group for completeness.

The Fukushima accident has highlighted several lacks considering air transport and inhalation dose assessment, deposition stage from atmospheric releases or long-lasting secondary emissions from previous deposits. Inhalation dose assessments have suffered from the relatively low-number determinations related to the gaseous iodine contribution. Attention should also be paid on the health effects of the particles, based on their size distribution, composition, crystalline structures, oxidation state influencing weathering rates and solubility in soil-water and sediment-water systems. Information on the source term and release scenarios is essential as input to atmospheric transport, and particle codes should be implemented in transport models. Regarding atmospheric processes, some peculiarities of winter time meteorological conditions such as snow and fog events have shown to be responsible for additional radionuclide deposition in some parts of the northern rim of the Kanto plain, Japan. The European situation is not very different from that of Japan both regarding the current capability to attest for a gaseous contamination and specific wintertime meteorological conditions. Such conditions would provide the same interactions of snowflakes or fog droplets with radionuclide-labelled aerosols in case of an accident release. Finally, the long lasting post-accident stage would be

also characterized by secondary emission through resuspension, biomass burning and biogenic aerosol production that remained to be fully understood despite some preliminary works performed after the Chernobyl accident.

Four objectives/tasks were put forward by the working group.

Task 1: Deposition: Deposition by fog, light rain and snow were pointed out as enhancing land contamination conditions after the Fukushima accident. This task is devoted to the definition of relevant range of values that makes it possible to characterize the importance of fog deposition, snow deposition, dry vs. wet only deposition in order to prioritize and assess deposition mechanisms according to meteorological conditions.

Task 2: Gaseous species: This task concerns improvement of various steps from sampling to measurement in order to lower the detection limit of gaseous species that represent most of the total (gaseous + particulate content) as in the case of ^{131}I and make a proper estimate of the gas/particle ratio. Two other subtasks will be devoted to understanding of the behaviour of gaseous species with time and interactions with airborne particles during transport, i.e.: the size distribution of the radioiodine-labelled aerosols and more especially the finest fraction arising from gas-to-particle conversion (heterogeneous nucleation), and the speciation of the two main gaseous species namely molecular iodine (I_2) and organic iodine (CH_3I) that would have the highest contribution in inhalation dose delivery. The final goal is to better assess the inhalation dose and help stakeholders in emergency phase for validation of countermeasures among them the distribution of stable iodine pills..

Task 3: resuspension and re-emission mechanisms: This task aims to have a better understanding and estimate of the long-term behaviour and fate of radionuclides in the atmosphere long after their initial deposition on terrestrial ecosystem. The Japanese society has expressed her strong will for land retrieval and land occupancy. New insights in this topic focus on bioaerosol emissions (pollens, spores, bacteria). The Fukushima accident also highlights more expected, but not least, resuspension process during decontamination works.

Task 4: Plutonium persistence at trace level and time series reconstruction; Characterisation of radioactive particles released from different sources. Results obtained last decade in Europe exhibit plutonium ratio that differs from the expected ones found in soils and resulting from the Chernobyl or global fallout.

Achievements

A PhD study on radionuclide deposition by fog droplets on vegetation will end October 2017. The results show that over the fog season (September – February) fog deposition enhance the total (wet + dry) deposition of radionuclide by 10 to 20%. As expected, the highest the plant canopy the highest the deposition by sedimentation and turbulent impaction. This study also shows that a simple deposition scheme based on a dry-type gravitational settling scheme is sufficient to improve the total deposition in case of fog.

A study was performed at the High-Alpine Environmental Research Station UFS Schneefernerhaus to find differences in deposition by rain and snow. Parameterizing the scavenging coefficient l as a

function of precipitation rate I using the equation $I = A \times (I / I0)^B$, is commonly done in decision support systems and atmospheric transport models. The values for A and B are fixed and do not depend on the type of precipitation. The most important result of this study is that precipitation events consisting of different types of hydrometeors can be parametrized by different values of A and B, for a range of precipitation rates from 0.1 mm h^{-1} to 4.0 mm h^{-1}. For water equivalent precipitation rates of less than 1.5 mm h^{-1}, snow turned out to show larger scavenging coefficients than rain. More specifically, the scavenging coefficients for snow and rain can differ by up to a factor 8 for precipitation rates of less than 0.5 mm h^{-1}. This can be one reason for the discrepancies observed in Fukushima between predicted and observed wet deposition.

Some preliminary determinations of the gas-to particle iodine ratio have already been achieved by members of the WG. Besides the release scenario, they show that close to a release this ratio much be higher by a factor of 10 than the one found on average after the Fukushima accident in Europe and worldwide. It clearly demonstrates that change in this ratio may occur between short and long distances.

Future steps

Next step will be to assess this change in the short to medium distances to assess for the kinetics of this modification. A new field experiment has been planned next summer in the vicinity of la Hague reprocessing plant to evaluate the size distribution of iodine (I-129)-labelled aerosols. The experiment benefits from the grant allocated by the Alliance. The development of a high-volume gaseous trap is almost finished and has been patented by IRSN. It will be tested in real conditions during 2017 and proposed to the atmospheric monitoring community next year.

Airborne Pu data will be gathered in a common publication in 2018 and some attempts finding the reasons and sources for the discrepancies with the expected global fallout and/or Chernobyl fallout will be investigated.

3.2.6 The roadmap WGs after COMET?

The topical roadmap working groups will continue after COMET since they serve as important nuclei or fora from which R&D is initiated or performed, and almost all the members of the ALLIANCE are involved at least in one of these WGs. The intention remains that by the shared effort of the participating organisations advances in science can be made, partially or largely based on own research funds. This is only possible when the participating institutes also partially angle their research priorities to the priorities of the global European radioecology research community as identified in the SRA and endorsed by stakeholders.

Following steps will be taken:

- Each Topical Roadmap WG could write a short document (1-2 pages) with the main objectives and task to be done in each roadmap, in order to use these documents to ask for funding to national agencies.

- Topical roadmaps should as a minimum maintain their function as discussion fora and organise one meeting a year and liaise where possible with other initiatives (eg. NORM roadmap WG with IAEA MODARIA II, EAN-NORM etc.)
- The ALLIANCE will organise a Topical Roadmap stakeholder consultation meeting which may affect the content/priority setting within the different Topical Roadmaps.
- ALLIANCE remains open for new roadmap initiatives. A "Hot particle" roadmap will be established. They will liaise with the IAEA-CRP on Hot particles.
- Each year, at the ALLIANCE General Assembly, the evolution/achievements of the different roadmaps will be discussed.

Topical roadmaps were/are building blocks to establish a global ALLIANCE roadmap at the end of 2017. This global roadmap will help in giving visibility to priority research to be implemented consistently with stakeholders' needs and request for associated funds. The strength of COMET was to facilitate the integration work at the European level, especially within the SRA/roadmaps WG. The EJP CONCERT extends this opportunity in a synchronised manner for all the platforms for research in Radiological Protection by programming the release of one global roadmap per platform for next November 2017 and of a joint research roadmap for all platforms in May 2019. See Chapter 5 and Deliverable 2.4 (Garnier-Laplace et al., 2017) that treats this aspect in more detail.

4. Radioecological observatory sites: a tool for innovative research, research integration and sustainability

Radioecological Observatories are contaminated field sites that provide a focus for long-term joint field investigations. The development of a pooled, consolidated effort maximises the sharing of data and resources. The Observatories also provide excellent training and educational sites. Four contaminated sites have been selected under the STAR NoE and COMET project as the most promising options for Radioecological Observatories.

The Observatory Working groups were formed under the COMET project to coordinate the RTD activities performed in the four Radioecological Observatories selected:

- Chernobyl Exclusion Zone (CEZ): contact person Nick Beresford (CEH, UK)
- Fukushima exclusion Zone (FEZ): contact person Hirofumi Tsukada (Fukushima University, Japan)
- Aquatic ecosystem in the former mining and processing area in Poland: contact person Boguslaw Michalik (GIG, Poland)
- Belgian waste landfill from phosphate industry "Kepkensberg": contact person Nathalie Vanhoudt (SCK-CEN, Belgium)

More information on the Radioecological Observatories can be found on the Radioecology Exchange website.

For the observatories to be successful in the future there needs to be a willingness amongst ALLIANCE partners to:

- Inform each other of research plans and be willing to be flexible on timetabling, such that local collaborators are not put under undue pressure and resources are best utilized;
- Openly invite participation from ALLIANCE members;
- Consider jointly supervised PhD studentships as a mechanism of collaborating for comparatively little external funding;
- Make data openly available.

The intensity of future studies that will be possible in the Radioecological Observatories are dependent upon funding.

The issue of the Observatory sites was also discussed at the COMET final event. There was general agreement that the ALLIANCE should continue promoting the Radioecological Observatories concept. It was noted that the Chernobyl, and to a lesser extent Fukushima, Radioecological Observatories had been shown to work – collaborative projects having been conducted both within and outside of COMET. It was recognised that whilst the ALLIANCE could co-ordinate activities at Radioecological Observatories that it would not be able to fund them.

All four groups discussing the issue at the COMET final event stated that for the Radioecological Observatories to be seen as successful to the wider community then data produced at them MUST be made openly available.

It was recommended that the Radioecological Observatories do not become a reason to conduct studies (i.e. 'we've got this Radioecological Observatories we need to do something there') but rather that they be used in hypothesis driven research. The hypotheses should come from the SRA, though, the Radioecological Observatories are note addressed in the SRA currently.

The Radioecological Observatories need to be advertised to researchers and funders: what research opportunities do they present, what infrastructure is on site etc.

With regard to suitability of the existing ROs it was suggested that Chernobyl and Fukushima were obvious sites for co-ordinated work. The lack of a marine RO was noted and potential additional ROs were suggested: Sellafield/NW English coastal area and a terrestrial site contaminated with Ra (as the Tessenderlo Radioecological Observatory).

5. Joint roadmap under CONCERT

Relationship with the EJP CONCERT and the Joint roadmap- The EC funded EJP CONCERT, in which the ALLIANCE is a partner along with the other research platforms (MELODI, NERIS, EURADOS and more recently formed EURAMED for the medical field), was launched in June 2015. CONCERT, more precisely its WP2 and WP3, now constitute the place for discussing the drivers of the SRA update in a harmonised manner with the other platforms. In addition to long term roadmaps to be produced by each of the four platforms under CONCERT-WP2, ALLIANCE and the other platforms are involved in a

Task from CONCERT WP3 (Task 3.3 – Joint roadmap development for a long term strategy of radiation protection research in Europe) under the coordination of MELODI. The first COMET brainstorming on the topic was during the Radiation Protection Week in Oxford. It was proposed to define the "R&D roadmap" as an "agreed detailed guide of what the problems are, raised by society's concerns or expectations, which the research is aiming to resolve. Breaking down these problems in sub-elements will facilitate the planning of research taking account of the state of the art, to define appropriate requirements and the road to accomplish them, from the near term to the longer term. Because the joint roadmap has to be founded on societal concerns, and because it will be associated with a clear description of major expected advances, the joint roadmap should allow instances in charge of the governance of research to take the appropriate budget and programming decisions. With such an approach, only a collective roadmap development for all platforms working together make senses, since scientific problems are closely interconnected, and stakeholders mostly common to several if not all platforms. However, once obtained, relevant parts of the road map could be selected by each platform for their own purposes. At present, the joint work has just been started by adopting an agreed definition of a Joint roadmap along with a first thought of "Reference societal scenarios" of interest. According to CONCERT, these are the key societal scenarios that challenge the existing radiation protection scientific knowledge, thereby justifying further research. These scenarios will take into account current societal models in Europe: open and democratic society, wide individual access to information and active NGO's. They should address the problems not in expert language of radiation protection, but result from a dialogue with stakeholders: risk identification, quantification and mitigation, cost benefit issues, societal expectations and hopes, etc.. The scenarios should, if possible, include a time line dimension, so that resulting priorities can be scheduled not only with respect to research possibilities, but also with societal expectations. The development of these scenarios could take advantage of the links being developed between the platforms and their key stakeholders. At the same time, such an enterprise would be likely to provide an incentive for stakeholders to participate actively in the cooperation with the platforms.

6. CONCERT CALL RESULTS

The European Project EJP-CONCERT, funded by EURATOM under Horizon 2020, launched the first open call for funding R & D projects in radiation protection in June 2016 (Figure 1).

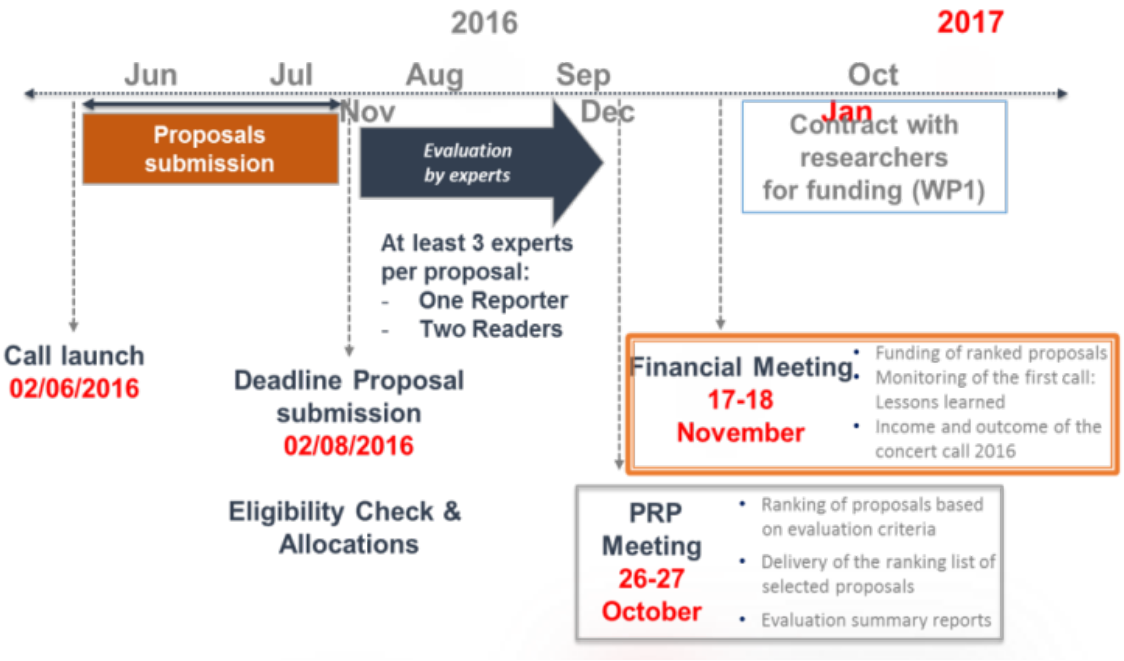


Figure 1: Calendar of the 1st EJP-CONCERT Call to fund RTD projects on radiation protection, launched in June 2016.

In the 1st EJP-CONCERT call, two research topics were defined:

1. Improve health risk assessment associated with dose and radiation dose rates.
2. Reduce uncertainties in the assessment and management of radiological risk for humans and ecosystems, in existing nuclear emergencies and exposures, including those related to NORM (natural radioactive materials).

A total of 12 proposals were submitted at the first EJP-CONCERT summit: eight on item 1 and four on item 2. A total of 26 countries and 147 partners from 85 institutions participated in the 12 proposals.

The 12 projects received were reviewed by at least three independent experts. Prior to the publication of the call, a database of independent experts was created to ensure that they are counted with a sufficient number of them for the value of all proposals received. For there to be no conflict of interest, the reviewers were from Australia, Canada, USA, Japan and Russia.

All the proposals were evaluated according to three evaluation criteria: Scientific excellence, Impact and Quality, and Efficiency for its implementation. Each of these criteria received a score of 0 to 5. Details on the evaluation criteria are used in the text of the call, at http://www.concert-h2020.eu/es/Calls/Transnational_Call_2016.

Proposals had to overcome a minimum evaluation of 10 points, to be considered for funding. Two proposals for theme 1 and three themes 2 exceeded this minimum score.

Taking into account that the budget available for this first EJP-CONCERT call was € 10.5 Million, the three projects that achieved the improved score were approved for funding. These projects are:

- CONFIDENCE (COping with uNcertaintie For Improved modelling and DEcision making in Nuclear emergenCIes), on topic 2, on reducing uncertainties to improve modelling and decision-making in nuclear emergencies. It has 32 partners.
- LDLensRAD (Towards a full mechanistic understanding of low dose radiation cataracts), item 1, on dose and risks in glass. It has 5 partners.
- TERRITORIES (To Enhance unceRtainties Reduction and Stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations), on topic 2, on Reducing uncertainties and increasing the involvement of stakeholders in order to manage people's risks and the integrated and gradual environment in existing exposure situations. It has 11 partners.

The projects officially started the 1st of January 2017 and will end the 31 of December 2019.

The 1st of March 2017, EJP-CONCERT launched a second transnational Call for Proposals to support innovative research projects in radiation protection (Deadline to present proposals 2 May, 2017). The call will address 2 main topics (each one having three sub-topics):

Topic 1 - Understanding human health effects from ionising radiation and improving dosimetry, which includes the subtopics:

I. Improvement of health risk assessment associated with low dose/dose rate radiation.
II. Improvement of occupational dosimetry.
III. Patient-tailored diagnosis and treatment: full exploitation and improvement of technology and techniques with clinical and dose structured reporting.

Topic 2 - Radioecology, emergency and social sciences and humanities, which includes the subtopics:

I. Biomarkers of exposure and effects in living organisms, as operational outcomes of a mechanistic understanding of intra- and inter-species variation of radiosensitivity under chronic low dose exposure situations.
II. Countermeasure strategies preparedness for emergency and recovery situations.
III. Models, tools and rationales for stakeholder engagement and informed decision-making in radiation protection research, policy and practice for situations involving exposures to ionising radiations.

The total budget available for the second EJP CONCERT transnational Call is 6.98 M€. Taking into account the projects funded in the 1st Call, EJP-CONCERT has decided to allocate the funds available for the second call as follows: 80% to topic 1 and 20% to topic 2, respectively.

All the details about the second EJP-CONCERT call can be found in: http://www.concert-h2020.eu/en/Calls/Transnational_Call_2017.

The CONCERT coordinator has informed that 24 eligible proposals have been submitted to the 2nd CONCERT Call: 20 proposals in Topic 1 and 4 proposals in Topic 2.

7. Conclusions

Through the topical roadmap working groups COMET has developed mechanisms of joint programming and implementation following the establishment of criteria and processes for prioritisation of programming research and we have set up sustainable implementation processes jointly with the ALLIANCE and in close interaction with the broader radiation protection arena represented by OPERRA and CONCERT.

The topical roadmap working groups will continue to function and elaborate their programme within the topical roadmap limitations (e.g. availability of funding) since they serve as important nuclei or fora from which R&D is initiated or performed. Following stakeholder consultation the content of the topical roadmap will be challenged and if and where required adapted. Topical roadmaps were/are building blocks to establish a global ALLIANCE roadmap at the end of 2017. This global roadmap will help in giving visibility to priority research to be implemented consistently with stakeholders' needs and request for associated funds. The strength of COMET was to facilitate the integration work at the European level, especially within the SRA/roadmaps WG. The EJP CONCERT extends this opportunity in a synchronised manner for all the platforms for research in Radiological Protection by programming the release of one global roadmap per and of a joint research roadmap for all platforms in May 2019.

There was general agreement that the ALLIANCE should continue promoting the Radioecological Observatory concept. They are a powerful tool for collaborative research. The intensity of future studies that will be possible in the Radioecological Observatories is dependent upon funding. Within the CONCERT infrastructure WP, there are funds available for infrastructure development and the Infrastructure WG will evaluated if and how ALLIANCE can claim part of this money. It was highlighted at several occasions that data from the Radioecological Observatories must be made availability.

References

Liland, A., Barnett, C.L., Beresford, N., Bradshaw, C., Brown, J., Calmon, Ph., Mora Canadas, J.C., Chmielewska, I., Duffa, C., Février, L., Gaschak, S., Iosjpe, M., Kasparov, V., Lahtinen, J., Michalik, B., Nanba, K., Outola, I., Real, A., Robles, B., Salbu, B., Skipperud, L., Simon-Cornu, M., Stark, K., Steine,r M., Thørring, H., Vanhoudt, N., Vives I Batlle, J., Vandenhove, H. 2013. Deliverable 3.1. Detailed plan for the COMET WP3 Initial Research Activity – list of research projects and goals, participants and timing. EC-COMET project - Fission-2012-3.4.1-604794 (restricted).

Vandenhove, H., Garnier-Laplace, J., Real, A., Horemans, N., Vives i Batlle, J., Beresford, N.A., Liland, A., Février, L., Adam-Guillermin, C., Beaugelin-Seiller, K., Barnett, C.L., Bradshaw, C., Gilbin, R., Hinton, T.G., Howard, B.J., Ikäheimonen, T.K., Muikku, M., Salbu, B., Simon-Cornu, M., Stark, K., Steiner, M. 2013. Deliverable 2.1 –Towards a First Phase Radioecology Alliance RTD Roadmap and Implementation Plan, EC-COMET project - Fission-2012-3.4.1-604794 (restricted).

Howard, B.J., Wells, C., Barnett, C.L., Howard, D.C 2017. Improving the quantity, quality and transparency of data used to derive radionuclide transfer parameters for animal products. 2. Cow milk J. Environ. Radioact. 167, 254-268. http://dx.doi.org/10.1016/j.jenvrad.2016.10.018

Howard, B.J., Wells, C., Barnett, C.L. 2016. Improving the quantity, quality and transparency of data used to derive radionuclide transfer parameters for animal products. 1. Goat milk. J. Environ. Radioact. 154, 34-42. http://dx.doi.org/10.1016/j.jenvrad.2016.01.009

Kashparov, V., Maloshtan, I., Levchuk, S., Polichuk, S. 2015. Analysis of long-term dynamics of radiocaesium mobility and plant availability in peat systems. Deliverable COMET IRA-Human-D1.

Levchuk, S., Kashparov, Howard, B. 2015. Long-term dynamic soil-to-plant transfers for Tc-99, Pu and Am. Deliverable COMET IRA-Human-D2.

Penrose, B., Johnson née Payne, K.A., Arkhipov, A., Maksimenko, A., Gaschak, S., Meacham, M.C., Crout, N.J.M., White, P.J., Beresford, N.A., Broadley, M.R. 2016. Inter-cultivar variation in soil-to-plant transfer of radiocaesium and radiostrontium in *Brassica oleracea*. J. Environ. Radioact. 155-156, 112-121. http://dx.doi.org/10.1016/j.jenvrad.2016.02.020

Penrose, B., Beresford, N.A., Crout, N.M., Lovatt, J.A., Thompson, R., Broadley, M.R 2017 Forage grasses with lower uptake of caesium and strontium could provide `safer' crops for radiologically contaminated areas PLoS one 12 (5): e0176040 https://doi.org/10.1371/journal.pone.0176040

Staudt, C. 2016a. HARMONE List of geographical dependent FEPs and associated model parameters. OPERRA Deliverable D5.35.

Staudt, C. 2016a. HARMONE Set of regions with common FEPs and parameters. OPERRA Deliverable D5.37.

Thørring, H., Dyve, J.E., Hevrøy, T.H., Lahtinen, J., Liland, A., Montero, M., Real, A., Simon-Cornu, M., Trueba, C. 2016. Set of improved parameter values for Nordic and Mediterranean ecosystems for Cs-134/137, Sr-90, I-131 with justification text. Deliverable COMET IRA-Human-D3. http://www.radioecology-exchange.org/sites/www.radioecology-exchange.org/files/COMET%20IRA%20Human%20Food%20Chain%20D3.pdf

Maloshtan, I., Polischuk, S., Khomutinin, Yu., Kashparov, V. 2015a. Dynamics of ^{137}Cs uptake to herbaceous plants at the peat-bog soils with abnormally high radiocesium bioavailability. Nuclear Physics and Atomic Energy, 16, No.3, p. 263-272. (Ukr.) http://jnpae.kinr.kiev.ua/16.3/Articles_PDF/jnpae-2015-16-0263-Maloshtan.pdf

Maloshtan, I. and Polischuk, S. 2015b. Radiological efficacy of non-traditional countermeasures on peat-bog soils. Nuclear Physics and Atomic Energy, 16, No.4, p. 381-388. (Ukr.) http://jnpae.kinr.kiev.ua/16.4/Articles_PDF/jnpae-2015-16-0381-Maloshtan.pdf

Maloshtan, I., Polischuk, S., Kashparov, V. 2016. Assessment of radiological effectiveness of countermeasures on peat-bog soils of northwest Polissya of Ukraine. Nuclear Physics and Atomic Energy, 17, No.3, p. 287-295. (Ukr.) http://jnpae.kinr.kiev.ua/17.3/Articles_PDF/jnpae-2016-17-0287-Maloshtan.pdf

Annex 1 – The roadmaps

Naturally-Occurring Radioactive Materials (NORM)

Topical area

The main issue in view of NORM-impacted sites[17] is how such sites, e.g. radium contaminated sites, uranium liabilities, sites exploited for the mining of metals associated with NORM and wastes arising from industries processing or generating other kinds of NORM, are assessed and regulated. In view of the implementation of the new Basic Safety Standards (BSS), the regulations apply to the management and clean-up of existing sites as well as to the licensing of future discharges and large quantities of NORM waste. This necessitates a better understanding of key routes involved in the migration and bioavailability of radionuclides at NORM sites, i.e. to develop (i) sampling strategies to characterize NORM-contaminated sites, (ii) the practical use of hydrogeological and hydrogeochemical mechanistic modelling together with a process-based understanding of radionuclide migration in abiotic and biologically influenced environments, radionuclide transfer into biota and finally into the human food chain, and (iii) projective modelling for existing sites as well as generic modelling for licensing procedures on timescales from years to millennia. Research in these directions will foster science based advice on the classification of NORM and NORM affected sites according to the recommendation and requirements set in the BSS and on the opportunity to undertake innovative and long-term effective remediation actions. It will also support the development of advanced generic radioecological models with a lower degree of conservatism, thus avoiding unnecessary restrictions in licensing procedures. Due to the complexity of NORM sites, which are characterized, for instance, by complex mixtures of different chemicals and minerals as well as disequilibria in radionuclide decay chains, challenges arise not only from the lack of comprehensive scientific data, but also from existing model concepts themselves, which do not adequately describe the interplay between simultaneously occurring processes at a NORM site. Therefore, a promising strategy is to reduce modelling uncertainties by identifying and parametrizing the key processes that influence the radionuclide behaviour and to transfer this knowledge into a mechanistic model sufficiently complex to describe the radionuclide behaviour in the environment, however, simultaneously simple enough to be practical and applicable to different NORM sites. In view of potential hazards associated with the radioactive source term of NORM sites related to former, current or future human activities, as well as the need for developing preventive methods at different stages of a technological process in a NORM industry, this is an important task.

WG group NORM currently is composed of 14 organisations from 10 European countries which contributed to the preparation of the current version of the WG NORM roadmap document. It contributes to Challenge 1 of the radioecology Strategic Research Agenda (SRA), research lines 1 to 3, by (i) identification and parameterization of key processes relevant for the environmental transfer of naturally occurring radionuclides and the resultant exposure of humans and wildlife, (ii) acquiring data necessary for the parameterization of key processes controlling the behaviour of radionuclides in the environment, and (iii) by improving existing models or developing parametric models linking observed accumulation, mobility (K_d), and transfer (TF and fluxes) with environmental parameters and processes to enable spatial and temporal predictions. The resulting knowledge is needed for a more reliable description and prediction of the behaviour of natural radionuclides in environmental compartments, including dynamic processes. This WG will generate new knowledge necessary to assess NORM

[17] The expression NORM in the document below denotes NORM (naturally occurring radioactive materials) sites as well as TENORM (technologically enhanced naturally occurring radioactive materials) sites.

resulting exposures of both humans and non-human populations with substantially reduced uncertainty.

Leadership

Susanne Sachs and Thuro Arnold (HZDR)

Partners with a brief description of their institutes

BfS: BfS (Federal Office for Radiation Protection; www.bfs.de) is an independent scientific-technical national authority in the portfolio of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. It pools the national expertise in the entire field of radiation protection, nuclear safety and radioactive waste management. BfS pursues, conducts and initiates application-oriented research in these fields. BfS is strongly involved in the radiation research platforms MELODI, ALLIANCE, NERIS, EURADOS and the medical field and co-ordinates CONCERT. A key issue in the radioecological research at BfS is to reduce the predictive uncertainty of radioecological models by identifying and explicitly modelling key processes. Here, the focus is on replacing highly uncertain empirical parameters by robust radioecological sub-models. BfS has extensive expertise in characterization, risk assessment and clean-up strategies of NORM legacy sites that resulted from uranium mining in Eastern Germany. In view of the implementation of the Basic Safety Standards, BfS aims at decreasing the degree of conservatism in generic assessment models, thus avoiding unjustified restrictions in licensing procedures, especially of NORM industries.

CEA: Different teams of the CEA (French Atomic Agency) study molecular mechanisms of radionuclide interaction with living organisms and toxicity, in link with their speciation. This involves the complementary expertise of chemists, biophysicists and biologists and concerns molecular studies on simple organic and inorganic model compounds, proteins, cell lines, and a variety of organisms including plants and soil bacteria. A transverse program “Toxicology” supports interdisciplinary projects in this field. We study NORM interactions with soil bacteria populations as well as mechanisms of interaction at the molecular level, to assess speciation, transfer, bioconversion or accumulation, and to identify protein targets, and markers of exposure, with a specific focus on uranium. In a context of integrative plant biology, using omics approaches combined with genetics and biochemistry, we evaluate the impact of NORM (notably uranium) on cell function and study biochemical and physiological defence mechanisms, as extracellular immobilization, active exclusion into the apoplast, chelation in the cytosol and sequestration in the vacuoles. Better understanding the molecular mechanisms controlling these processes, metal toxicity and accumulation in plants, will enable to identify biomarkers of exposure and to design new strategies of phytoremediation via engineered plants, natural hyperaccumulators, or the selection of crops with low radionuclide accumulation.

CIEMAT: The CIEMAT is a Public Research Institution belonging to the Spanish Ministry of Economy (within the secretary of research and development). It promotes and carries out research and technological development projects in the field of energy, keeping as far as possible close connections with other national and international research groups with similar objectives. Likewise, it is the link between basic research and the national industry, acting when requested as an adviser of our national authorities in the fields of technology and energy strategy. The CIEMAT acts as technical supporter for regulators and operators, providing methodologies, tools, analytical services and performing radiological impact assessments for solid waste disposal, effluent releases and "ad hoc" situations of environmental contamination. Its activities in radiological protection extend to the public and the environment through studies on radioecology, evaluation and reduction of radiological impacts,

environmental radioactivity measurement, as well as personal and environmental dosimetry. The CIEMAT has an important activity in training/education of professionals (radiation protection, radioactive waste management, nuclear safety), and a wide experience in organizing workshops, conferences and other events (www.ciemat.es).

CLOR: Central Laboratory for Radiological Protection (Centralne Laboratorium Ochrony Radiologicznej) is a research institute situated in Warsaw, Poland. Our primary activities are monitoring of radioactive contamination in foodstuff, environmental components and building materials, calibration of dosimetric instruments and monitoring of occupationally exposed workers as well as the general population. We conduct research on matters dealing with radiation protection, radiobiology and radioecology. CLOR perform dose assessments both for humans and wildlife exposed to artificial and natural ionizing radiation. Our recent projects related to NORM were connected with phosphogypsum waste dumps and also former uranium mining sites located in Poland. CLOR serves as a centre for training in radiation protection, scientific and technical information and developer of high-sensitive stations for detection of radioactive contamination in air. Furthermore, from 2012 CLOR became Technical Support Organization by bilateral agreement with the President of the National Atomic Energy Agency.

GIG: Główny Instytut Górnictawa (GIG; Central Mining Institute) is located in Katowice, the administrative centre of Silesia, a mining and industrial region in southern Poland. GIG is a research and development institute, working for mining industries, local authorities, environment protection businesses and other customers. The tasks, related to radioprotection and radioecology, are run by the Silesian Centre for Environmental Radioactivity (SCRS), the modern, well equipped GIG's department. The SCRS' team has been involved in the problems caused by NORM at industrial and post-industrial areas for many years. It results in extensive experience in radiation measurements, occupational risk assessment and monitoring of the environmental impact related to natural radioactivity (NORM). Besides mining industry the main scientific activity of SCRS is currently directed into protection of widely comprehended environments against ionising radiation, including, e.g. non-human biota, effects related to the simultaneous presence of other toxic metals and different environmental conditions or radon and radon progenies in homes. During the last few years SCRS participated in EU projects mainly focused on radiation protection and environmental effects related to activities of the non-nuclear industry. SCRS has experience in training in radiation protection and NORM waste management and can provide excellent conditions for trainings and exercises focused on radiation protection and radioecology. SCRS provides almost all measurement techniques useful in radiation protection and radioecology.

HZDR: The Institute of Resource Ecology (IRE) is part of the Helmholtz-Zentrum Dresden-Rossendorf (HZDR). Research activities of the IRE are focused on the assessment and reduction of risks related to the nuclear fuel cycle and the migration of radionuclides in natural environments, based on a profound knowledge of molecular processes at the interface between geo- and biosystems. The IRE combines earth sciences, biochemistry, chemistry, and biology. It has ample experience with the characterization of environmental problems (mostly in connection with former uranium mining). These activities include low level nuclear radiation measurements, sophisticated spectroscopies, modelling of thermodynamic equilibria and migration processes, interactions of microbes or plants with radionuclides, sorption phenomena, colloid chemistry, and solubility and speciation studies. IRE combines spectroscopic, microscopic, and biological methods in controlled areas allowing studies that can only be performed at a few places in Europe. IRE runs the X-Ray absorption spectroscopy station for radiochemistry, the Rossendorf Beamline, at the European Synchrotron Radiation Facility in Grenoble (France). In addition, a number of different chemical speciation codes are in use. HZDR is the leader of WG NORM. More information is provided at www.hzdr.de.

IRSN: The Institute for Radiological Protection and Nuclear Safety (IRSN) provides expertise and research in nuclear safety and radioprotection of human health and the environment. IRSN has a strong experience in the field of risk associated to uranium mining, NORM activities and contaminated sites management. IRSN contributes to the development of technical and regulatory documents on uranium mining and NORM activities in support to the French national authorities and at the international level. IRSN experts are regular contributors to IAEA activities. IRSN also performs its own environmental and human impact assessment of radionuclides, alone or combined with other stressors, and contributes to the development and the implementation of national and local environmental monitoring programs around uranium mining and milling sites. IRSN conducts R&D works devoted to a better understanding of radionuclides transfer and impact in the environment and develops its own transfer modelling tools. IRSN has several laboratories, particularly to perform radiological analyses on effluent releases and environmental samples for all radionuclides of interests (e.g. uranium and thorium), in support of monitoring and R&D related activities.

IST: IST is the largest and most reputed school of engineering, S&T in Portugal. Its mission is to provide top quality higher education in the areas of engineering, S&T and architecture, as well as developing RD&I activities that meet the highest international standards. The IST has expertise, among others, in nuclear physics&engineering, radiological protection and nuclear safety, nuclear techniques, environment&cultural heritage and runs specialized equipment and infrastructures, unique in the country. IST combines nuclear analytical techniques (INAA), spectrometric methods (gamma spectrometry, LSC, etc.), microscopic techniques (SEM-EDS), luminescence measurements, Mössbauer spectroscopy (MS), X-ray diffraction and mineralogical and granulometric methods for the precise and accurate determination of NORM sites, their distribution in different size fractions of soils and sediments, and the identification of the host phases in NORM materials. More information is provided at http://c2tn.tecnico.ulisboa.pt/.

LRA-UAB: The Laboratory of Environmental Radioactivity (LRA) at the Universitat Autònoma de Barcelona (UAB) is a research group specialized in natural and artificial environmental radioactivity at different fields (oceanography, radiochronology, NORM industries, radioecology, …). LRA-UAB has been worked in several NORM environmental areas focused on the determination and distribution of radioactive elements and their effects related to dose assessments of the human health and environment. These NORM studies have been mainly dedicated to the phosphate industry and water characterization in several water management processes. The LRA-UAB has an environmental radioactivity laboratory, sampling equipment's and radionuclide detectors for radionuclide spectrometry.

NCSR"D": The National Centre for Scientific Research "Demokritos" (NCSR"D") is the largest multidisciplinary research centre in Greece, with critical mass in expertise and infrastructure in the fields of nanotechnology, energy&environment, biosciences, particle and nuclear science, informatics and telecommunications. Research activities are currently coordinated by five research institutes; one of them is the Institute of Nuclear&Radiological Sciences&Technology, Energy&Safety (INRASTES). INRASTES is an interdisciplinary institute with a large part of its scientific activities centred around nuclear technology, energy/environmental technologies and radiation protection, molecular radiopharmacy and biodiagnostics. It is a multidisciplinary research institution pursuing basic, translational and applied research to address challenges of great scientific and socioeconomic impact in a broad spectrum of scientific and technological fields. The various activities have been organized in four thematic areas (divisions): (1) energy/environmental technologies&safety, (2) nuclear technology, (3) biodiagnostics, (4) radiological sciences and radiopharmaceutics. All these thematic areas share a common background in physical sciences and are in line with both the Horizon 2020 priorities and the national smart specialization areas.

NERC-CEH: The Natural Environment Research Council (NERC) employs over 450 staff at four sites. The Centre for Ecology and Hydrology (CEH) is the UK's Centre for Excellence for integrated research in terrestrial and freshwater ecosystems and their interaction with the atmosphere. Our science is organised within three programmes, Biodiversity, Water and Biogeochemistry with an overarching Environmental Informatics Data Centre. The Radioecology group has extensive experience in the development and testing of approaches to demonstrate radiological protection of the environment (e.g. ERICA, PROTECT, IAEA EMRAS chairs, ICRP TGs), spatial transfer model development (e.g. SAVE), farm animal radioecology, and countermeasure development and strategies (e.g. STRATEGY). The group (together with IRSN, SCK•CEN and the University of Stirling) developed training packages in radiological environmental assessment. NERC-CEH currently co-ordinates the TREE consortium (http://www.ceh.ac.uk/tree). The chemical and radiochemical laboratories of CEH in Lancaster are UKAS accredited (ISO17025).

NMBU: The Centre of Environmental Radioactivity (CERAD CoE) at Norwegian University for Life Sciences (NMBU) is established to perform fundamental long term research to improve the ability to accurately assess the radiological risks from environmental radioactivity combined with other stressors. By focusing on key factors contributing to the uncertainties, CERAD represents a state-of-the-art research foundation for the advancement of tools and methods needed for better management of those risks. The scope includes both man-made and naturally occurring radionuclides that were released in the past, those presently released as well as those that potentially can be released in the future from the nuclear fuel cycle and non-nuclear industries. For more information, see https://cerad.nmbu.no.

SCK•CEN: The Biosphere Impact Unit (BIS) is part of the Institute for Environment, Health and Safety (EHS) of the Belgian Nuclear Research Centre (SCK•CEN). Our major objectives are (1) to enhance competence in the understanding and process-based modelling of the behaviour of radionuclides in the biosphere, (2) to develop a groundwater-soil-vegetation interaction model to assess the long-term impact of perennial vegetation systems on the dispersion of radionuclides and contamination of the food chain, (3) to study biological effects induced in plants by radiation, radionuclide uptake and mixed contaminant conditions at different levels of biological organization and (4) to develop and improve our tools and models for assessing the radiological impact on man and environment. To better understand and predict the processes that determine radionuclide mobility, transfer, etc. in the terrestrial, freshwater and marine environment, we use dedicated laboratory set-ups, greenhouse experiments and field studies as well as develop modelling tools calibrated and validated with the available data sets.

STUK: Radiation and Nuclear Safety Authority (STUK) of Finland operates in the regulation of ionising and non-ionising radiation, e.g. regulation of nuclear energy and reducing radon exposure, and in emergency preparedness. One of the official duties is to monitor the radioactivity in the environment using various methods. The main goal of the environmental radiation monitoring is to get detailed information on the radiation exposure of the Finnish population, whether it is from natural or artificial radiation sources. Another goal is to detect all significant changes in the levels of environmental radiation and radioactivity to identify foreign substances and provide information for protection procedures. The running of an environmental surveillance programme on a continuous basis maintains and develops competence and readiness to respond to radiological emergencies. Specifically for NORM, through changes in legislation in 2015 the role of STUK in the regulation of the mining industry has been strengthened. In the near future the focus related to NORM will be on the implementation of the BSS as well as carrying out radiological baseline studies. In addition, small-scale investigations

might be carried out in the former and existing mine sites in order to gain knowledge on the local radiological situations to support the implementation of the BSS.

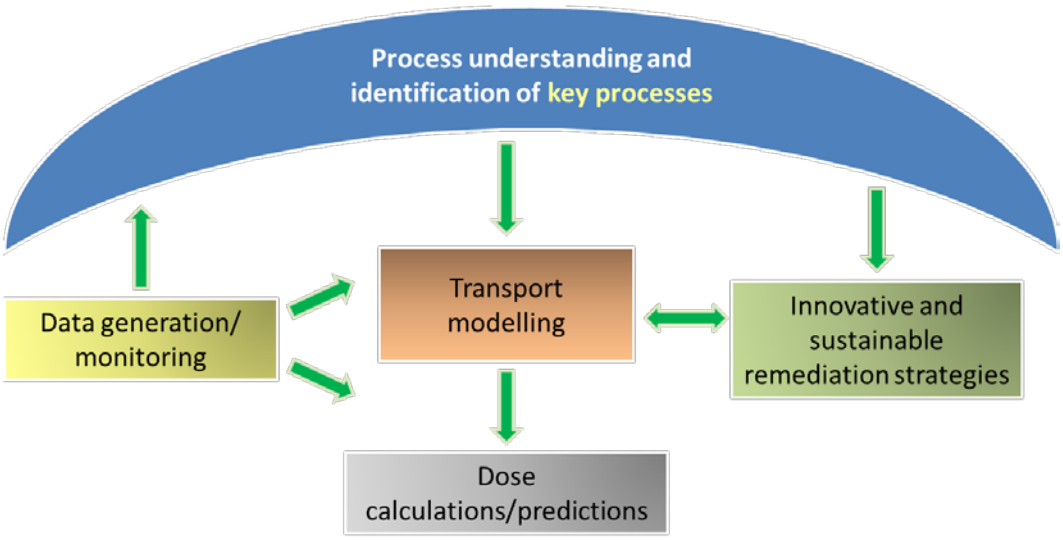
Intended activities (task, approach, steps to accomplish, expected outcomes)

This roadmap covers a time frame of five years; however, we are aware that there are important activities in future R&D that are beyond our immediate scope. But, the here described roadmap is part of a prolonged vision aiming at continuously incorporating new knowledge, when it becomes available, to progressively improve risk assessments of NORM contaminated sites and thereby help to reduce the risk for humans and wildlife.

The **main objectives** of the WG NORM can be summarized as follows:

1. Improve risk assessment for existing and future NORM sites.
2. Extend transport modelling of radionuclides into the uncontaminated environments by including chemical/geochemical, biological/microbiological, and mobilization/immobilization processes, i.e. by to identify and mathematically describe processes that make significant contributions to the environmental transfer of radionuclides resulting in extended exposure of humans and wildlife.
3. Develop a mechanistic understanding of chemical and biological processes on a molecular scale and translate this knowledge into robust sub-models thus paving the way for new strategies for a sustainable rehabilitation and remediation of NORM sites.

To be able to achieve these objectives a multidisciplinary approach is required. The power of multidisciplinary teams working jointly together on environmental issues in Europe should result in synergies, from which the radioecological community will benefit, and helps to achieve such a goal in an efficient way. Based on these objectives and the expertise of the contributing partners, a general structure of WG NORM was developed, which shows its main tasks and their respective relationships.



Main working tasks of WG NORM.

There is a strong link between all tasks of WG NORM. For example, knowledge generated in task "Process understanding and identification of key processes" will feed into task "Transport modelling". Both tasks will feed into task "Dose calculations/predictions". In turn, with this task major uncertainties

will be identified which will feed back into new requirements on process understanding and transport modelling.

The starting situation of WG NORM is the following: in a number of European countries there are NORM sites of interest, resulting from mining activities (e.g., U, Zn, Cu mining, Upper Silesian Observatory Site) and phosphate industry (e.g., phosphogypsum stock pile, phosphate production plant, pine forest on a sludge heap from the phosphate industry), which may cause health hazards for humans and the environment. These NORM sites are already under investigation, however, predominantly on a national level. Due to the fact, that there is no EU funding for WG NORM and no foreseeable funding at the moment, each partner currently contributes to the tasks of WG NORM with their own data, skills, knowledge, and financing from national and international sources (projects, grants, funds).

The work of WG NORM will create a research platform for NORM interested scientists for sharing and exchanging knowledge on radionuclide behaviour in the environment. Thereby, studies made by the European platform EAN-NORM (European Alara Network for Natural Occurring Radioactive Materials) will be considered to make sure that activities are not duplicated. It aims at reducing the uncertainty of human and environmental risk assessment for NORM via an improved mechanistic process-based transport modelling and by integrating chemical process understanding (e.g. multidimensional K_d) as well as biological/microbiological processes in transport codes. The **added value for the society** can be found in: (i) improved transport models for radionuclides with reduced model uncertainties, (ii) more reliable and less conservative assessments of the radionuclide transfer, (iii) new innovative, cost-effective and sustainable remediation measures of NORM sites, and (iv) licensing procedures of NORM industries that provide adequate protection of humans and the environment without unnecessary restrictions.

The planned research in WG NORM offers the possibility to link its efforts with other topical roadmap WGs within the ALLIANCE and it is also linked to other radiation protection research platforms in Europe, especially with MELODI.

Starting date and estimated duration of the WG to accomplish its plan

Starting date: October 1, 2015

Duration of the WG: 5 years

Work plan

Based on the strong expertise and the comprehensive topical contributions of our different partners the following tasks will be studied in the next five years in order to reach the objectives of WG NORM. Currently, all partners work or relate their laboratory work to different European NORM sites and for their research they use their own funding (national/international). Radionuclides of interest include, among others U, Th, Ra, Rn, ^{210}Pb, ^{210}Po.

<u>Task 1:</u> Data generation/monitoring

- Compilation of hypotheses and research questions that guide data generation and monitoring
- Radionuclide fluxes in NORM sites → Determination of radionuclide activities (e.g., U, Th, Ra, Rn, ^{210}Pb, ^{210}Po)
- Physicochemical characterization of soils → Determination of simple TF and K_d values and correlation with the physicochemical parameters of the NORM site

- Identification of interaction constants between radionuclides and inorganic/organic compounds to be integrated in transfer models

Task 2: Process understanding and identification of key processes

- Identification and parameterization of radionuclide transfer in plants and microorganisms including the prevailing radionuclide speciation
- Molecular understanding of the radionuclide interactions with simple inorganic and organic model compounds, proteins, cells, bacteria and plants considering their different organs, cell types, and sub-cellular compartments
- Soil-to-plant radionuclide transfer
- Influence of co-contaminants, e.g., heavy metals, on the transport behaviour of radionuclides
- Radionuclide transfer considering redox processes and reactive transport processes
- Use of geochemical speciation databases and codes to support the interpretation of results (such as BASSIST, DACTARI, WHAM, JCHESS, PHREEQC, Geochemical Workbench, …)

Task 3: Transport modelling

- Development of modules for transfer and exposure models that incorporate physical, chemical and biological interactions

Task 4: Dose calculations/predictions

- Calculation and modelling of total doses related to external and/or internal exposures depending on radionuclides and scenarios, e.g., (i) a solid waste disposal site with a vegetation cover, (ii) a natural site contaminated by the release of NORM waste into the environment, and (iii) a natural enhanced site

Task 5: Innovative and sustainable remediation strategies

- Engineering of affine and specific binding sites in proteins and in simple model compounds such as peptides
- Water decontamination using selected hyper-resistant and/or hyper-accumulating microorganisms (bacteria, microalgae) at micro-pilot scale and high-affinity chemicals, peptide derivatives or proteins
- Purification of radium rich water released from fossil fuel mining industry into terrestrial and aquatic ecosystems

Milestones

The following milestones have to be accomplished in order to reach the main objectives:

1. Define, select and generate data necessary for (i) building up a mechanistic understanding, (ii) needed as input in transport codes

2. Development of chemical modules suitable to be included in NORM related transport models (e.g., compartment models)

3. Identify and parameterize mobilization and immobilization processes of NORM radionuclides with plants and microorganisms considering radionuclide speciation

4. Development of a first concept for microbiological/botanic modules suitable to include in transport models (e.g., compartment models)

5. Publication on a process-based modelling approach describing the migration behaviour of radionuclides from NORM sites to uncontaminated environments by including chemical and biological processes

Partners with a brief description of their assigned role (contributions of NORM partners in alphabetic order)

BfS: BfS is mainly interested in identifying and modelling key processes that affect the transport of natural radionuclides in the environment, especially in large quantities of NORM waste (Tasks 2, 3). Here, the focus is on the potential contamination of groundwater and the resulting dose to humans (Task 4). BfS will apply state-of-the-art codes for the water-bound transport of radionuclides (e.g. HYDRUS) in combination with hydrogeochemical speciation modelling (e.g. PHREEQC). BfS is also interested in the further development of generic radioecological models for large quantities of NORM waste with the aim of reducing the predictive uncertainty. These advanced generic models are intended to provide the basis for licensing procedures as well as reference levels for the release of NORM sites from regulatory control. The results will be used to implement the EURATOM Basic Safety Standards. In summary, BfS will mainly contribute to Tasks 2, 3, and 4.

CEA: - Molecular mechanisms governing the interaction of uranium with model compounds, peptides and proteins, soil and water bacteria, microalgae, and plants.
- Molecular origin of resistance, accumulation, and transport mechanisms (including translocation and subcellular distribution in plants and in the microalgae *Coccomyxa actinabiotis and* the role of post-translational modifications PTMs in plant response to uranium) to better describe uranium bioavailability and transfer in ecosystems.
- NORM soil-plant transfer characterization with a selection of mutants or transporter-overexpressing plants, effect of speciation and soil bacteria.
- Isolation of radioresistant microorganisms able to live in various conditions and possessing radionuclides accumulation capacities for the development of bioremediation processes. Decontamination of environmental water with NORM using *Coccomyxa actinabiotis* at micro-pilot scale using a micro-pilot process. Assessment of peptide/protein-derived water-remediation properties.
- Contribution to the databases BASSIST (base applied to speciation in solution, at interfaces and solubility, https://inis.iaea.org/search/search.aspx?orig_q=RN:35016056) and DACTARI for chemical toxicity and radiotoxicity assessment of radionuclides (http://www.dactari.toxcea.org/)

CIEMAT: The CIEMAT is interested in the identification, modelling and parameterization of key processes affecting the behaviour of natural radionuclides transfer. The group has experience and knowledge in the implementation and application of soil-to-plant natural radionuclide transfer models. The CIEMAT is also interested in the development of conceptual and mathematical models for the assessment of natural radionuclides transport, transfer and exposure, looking for processes where uncertainties can be reduced (Task 3). By using key examples to demonstrate the importance of key processes in the doses (effective or absorbed) to biota and humans, the group can contribute to the validation of models (Task 4). CIEMAT can prepare dose scenarios for the derivation of clearance or guidance levels, for remediation or clearance of NORM contaminated sites from the regulatory control. Also following MARSSIM methodology (Multi-Agency Radiation Survey and Site Investigation Manual),

the group can contribute in the design of sampling strategies for NORM sites (Task 1). Therefore, the CIEMAT will mainly contribute to Tasks 2, 3, and 4. If appropriate, it can also contribute to Task 1, in the design of the sampling strategies.

CLOR: CLORs recent projects were related to dose assessments of human and wildlife in the vicinity of phosphogypsum waste dumps and former uranium mining industry located in Poland. These work as well as our current interest include measurements and sampling methods (Task 1), calculation of soil-to-plant radionuclide transfer (Task 2), modelling with the use of ERICA tool, RESRAD family codes etc. (Task 5) and long term monitoring strategies. Regarding NORM, our experience and statutory activity is mainly focused on dose assessments and environmental monitoring.

GIG: GIG is interested in the investigation of all aspects related to an assessment of the impact caused by radium rich waters released into terrestrial and aquatic environment from coal mining industry, oil and gas industry including shale gas exploitation; the identification of processes leading finally either to accumulation or dilution of radionuclides in particular compartments of the environment; the classification of NORM affected sites according to the requirements of the new BSS; identification and development of well scientifically justified methods of NORM effects on environment assessment founded on genotoxicity and cytotoxicity of radionuclides that can be easily applicable in routine monitoring of NORM affected sites.

HZDR: HZDR is interested in the identification and quantification of key processes that play an important role in the transfer of radionuclides in the environment. Fields of applications are related to uranium mining and possibly phosphate industry, and geothermic work places. This includes studies on the interactions and the mobility of radionuclides at the interface between geo- and biosystems. It is intended to investigate the uptake of radionuclides by microorganisms (e.g., bacteria, archaea, and eukaryotic microorganisms) and plants on a molecular level. The radionuclide uptake will be studied as a function of the radionuclide speciation, which will be identified by state-of-the-art spectroscopic techniques and geochemical modelling. Key processes of the interaction of radionuclides with microorganisms and plants will be identified and parameterized. These new data will then be used as basis for the development of basic concepts for modelling of the radionuclide transfer by considering biological processes.

IRSN: IRSN is interested in a better understanding of the geochemical mechanisms that control radionuclide mobility through the aqueous pathway in the environment of mine sites. In that context, IRSN will mainly contribute to Tasks 1 and 2. For Task 1, IRSN currently uses and develops tools, such as diffusive gradient in thin films (DGT) associated with isotopic analyses, to identify sources of radionuclides that mix through aquatic interfaces (*e.g.* discrimination between mine waters, treated waters, ground waters, surface waters, etc.). Such DGT are used for uranium and under development for radium and thallium. Concerning Task 2, IRSN can contribute to a better understanding of the redox processes in the transfer of NORM. Effectively, IRSN currently studies the redox interface sediment/water and develops solution extraction devices for sediment cores under anoxic conditions. IRSN is also interested in the study of NORM speciation in the presence of natural organic matter. For this, IRSN develops methods to study NORM interaction with natural organic matter through fluorescence spectroscopy. In support of these studies, IRSN uses regularly different codes for reactive transport in soils and underground waters (Hytec, Modflow) or geochemical speciation modelling (Chess, Phreeqc, Visual Minteq, WHAM). Finally, IRSN can also provide expertise on the understanding of the key processes that control uranium bioavailability, uptake and accumulation in biota (plants, bacteria, fishes), internal speciation, biological effects as well as on the ecological risk assessment. IRSN has developed an integrated approach to take into account chemical and radiological toxicity, bioavailability, multi-pollutants, disequilibrium in decay chain, as well as natural background. This

method has already been applied to former uranium mining areas in France. IRSN can also contribute to Task 4, with the use of its own tool for dose calculation to biota (EDEN).

IST: IST will contribute to setup sampling strategy and methods, to the chemical, physical and radiological characterization of NORM samples resulting from current and past Zn, Cu and U mining activities as well as historical phosphogypsum tailings. This part of the work will be supported by the use of a robotized sampling vehicle-Introbot Sampler, built by a Portuguese company in collaboration with IST. This equipment has already been tested in previous projects but it will be tested for the first time in phosphogypsum tailings and in the inter-tidal sediments area surrounding the phosphogypsum tailings to collect samples. Studies following up sampling will also be developed by IST such as: the distribution of the radionuclides concentration in host phases in phosphogypsum residues; the evaluation of phosphogypsum influence in the surrounding environment (soils, sediments, water, salt marsh plants, estuarine seaweeds and bivalves); the soil-plant radionuclide transfer in different phosphogypsum/soils ratios; and the identification of the vegetal species that can act as bioindicators for trace metals and radionuclides. The development of new methodologies and measurement devices for measurement of natural radionuclides (expected outcome of IST participation in other NORM related international projects) as well as new reference materials adapted in an appropriate manner to the real composition and geometry of measured samples, assuring the traceability to national standards will also be performed.

LRA-UAB: The Laboratory of Environmental Radioactivity (LRA) is interested in: (i) developing radiochemical techniques to measure radionuclides from different biological or geological matrices, as well as contributing to the design of sampling strategies (Task 1); (ii) quantification of radionuclides derived from NORM activities in different industrial, natural and biological environments (Task 1); (iii) understanding the transfer mechanisms of radionuclides from NORM production plants to the environment (Task 2); (iv) understanding the accumulation factors of radionuclides in biota (Task 2); and (v) evaluating the potential external and internal doses for human and animals (Task 4).

NCSR"D": In terms of radioecology/environmental radioactivity the current research and technological activities in NCSR"D"are focused on: (ii) development of a user-friendly, ready-to-use by stakeholders, commercial organism-kit for environmental quality assessment purposes based on the impact level, (ii) providing an innovative tool for the remote control of the radioactive releases in the marine environment from local and/or regional/global radiological events, (iii) pursuing improvement in modelling by introducing further biological parameters for more accurate estimations of doses to non-human organisms and model inter-comparison and validation. Considering NORM, NCSR"D" is interested in: radiological impact assessment and natural radionuclide transfer in NORM sites (areas of elevated natural radioactivity in the vicinity of geothermal mineral springs), effects on non-humans by the protracted exposure to elevated ionizing radiation (but non-intervention levels), dose rate estimations from natural radionuclides especially of ^{222}Rn through different pathways for various groups of exposed humans (e.g. spa installations) and as it is reported above, use of models for dose rate calculation and risk prediction. Besides, innovation is focused on the use of cytogenetic tools for field observations of the effects of protracted low levels of ionizing radiation and the synergistic action of various pollutants on natural population in NORM sites (areas of geothermal mineral springs).

NERC-CEH: NERC-CEH will only have a minor contribution to this WG. We will be developing alternative transfer (REML) models which will include some NORM radionuclides (including U). NERC-CEH will also provide a link to the TREE project in which other organisations are focusing on uranium biogeochemistry and also application of DGT (diffusive gradient in thin films; NERC-CEH co-supervised PhD) to predict plant uptake of a range of radionuclides (including NORM elements).

NMBU: NMBU will contribute to the identification and mathematical representation of key processes that play a role in the environmental transfers of radionuclides. Data necessary for the parameterisation of key processes controlling the transfer of radionuclides will be acquired. We will contribute to the development of transfer and exposure models that incorporate physical, chemical and biological interactions. By making the models more realistic and process-based, it is expected to more accurately assess radionuclide transfer between and within environmental compartments and as such assure more robust human and ecological impact assessments. To achieve this, time dependent K_d values for NORM contaminated soils from different origin will be determined and linked with soil characteristics. Also, soil-to-plant TF for NORM contaminated soils will be determined and linked with soil characteristics and radionuclide speciation. We also want to look into if the presence of co-contaminants changes the mobility and uptake of NORM by terrestrial plants.

SCK•CEN: SCK•CEN is interested in the identification, modelling and parameterisation of key processes controlling the mobility and transfer of natural radionuclides and radiological impact assessment of releases from NORM sites (Tasks 1, 2, 3 and 4). We will determine K_d and TF values for ^{232}Th, ^{210}Po and ^{210}Pb on fully characterised (i.e. particle size distribution, organic and mineral content, CEC, etc.) spiked soils and soils from NORM contaminated sites (Tasks 1 and 2). For the monitoring part of Task 1, SCK•CEN will take samples of a 20 year old pine forest present on a sludge heap from the phosphate industry in Tessenderlo, Belgium. The data generated will allow to identify what soil properties control radionuclide mobility and soil-to-plant transfer in the environment. We can contribute to Tasks 3 and 4 by applying hydrological and reactive transport models, mainly HP1 code which combines the water flow and solute transport simulator HYDRUS-1D and the geochemical modelling code PHREEQC to assess the performance of reactive transport modules developed in this WG and to provide activity concentrations in environmental media as inputs into radiological impact assessments. For the radiological impact assessment we will apply our biosphere code to calculate doses received by humans of different age groups arising from different exposure pathways.

STUK: STUK regulates and monitors mines and industrial facilities that produce, intend to produce or have radiological issues with NORM. The monitoring data from e.g. a nickel mine which has issues with soluble uranium (and also intends to produce uranium) is public and is therefore available for use for transport modelling or other studies related to transport of NORM in the environment. Also if any NORM-contaminated site in Finland becomes regulated by STUK, the monitoring data will be public and can be used for other studies, if external funding is secured.

EC Calls

Within this WG NORM there are important R&D activities in future, so that there is a basis for the development of a call for proposals under CONCERT.

- January 2016 and January 2017 first and second CONCERT open call, respectively
- Identification of upcoming calls within HORIZON 2020

Major elements of the communication plan

Continuing professional development

- PhD students (HZDR, IRSN, NMBU, SCK•CEN each with one PhD student)
- Shared supervision of PhD students?

Workshops

- September 2015: presentation of the ALLIANCE and especially WG NORM took place at the Nordic NORM workshop in Helsinki, Finland by Maarit Muikku (STUK)
- Presentation of NORM topics at the radiation protection week 2016 in Oxford, UK and at the ICRER conference 2017 in Berlin, Germany
- NORM session within the ALLIANCE workshop in 2017 (to be confirmed)
- Financial support and collaboration in organisational issues by the ALLIANCE is required in order to organize the above mentioned activities

Knowledge dissemination

- Publications of the participating institutes (peer-reviewed journals, contributions to national and international conferences)
- PhD theses
- Joint publication of WG NORM members after two years and at the end of the 5 years period
- Popular scientific presentations (lectures, posters), e.g., at travelling exhibitions of Kompetenzverbund Strahlenforschung, Dresden Long Night of the Science, Open Laboratory Days

Links with other activities identified at the national and the international levels (contributions of all partners in alphabetic order)

BfS: BfS is strongly involved in the radiation research platforms MELODI, ALLIANCE, NERIS, EURADOS and the medical field. It coordinates the project CONCERT and participates in the project COMET. At the national level, BfS cooperates with the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, for which BfS provides the scientific-technical basis of legal regulations.

CEA: TOXICOLOGY, the French *'CEA Transversal Programme of Toxicology'*

NCSR"D": The task can be carried out in the frame of the program "Preparation and evaluation of environmental studies", a technological research program (NCSR"D" EE 10950) self-funded under contracts, in compliance with the Decision of the Greek Ministry of Tourism, No. 17414/02-10-2009, on the identification process of thermal natural resources (Official Gazette 2215/02-10-2009). Our participation in MODARIA activities can support the program activities. Besides, a candidacy for a MSc work is being carried out focused on dose rate modelling.

NERC-CEH: UK TREE project has uranium as one of the priority radionuclides (http://www.ceh.ac.uk/tree)

CIEMAT: CIEMAT has participated in many relevant international projects related with modelling, specifically in NORM (BIOMOVS-II; BIOMASS; BIOPROTA; FUTURAE; FASSET; ERICA; EMRAS-II; MODARIA; EAN-NORM; NORM4BUILDING, METRONORM...). The organization was partner of the European NoE STAR, and is one of the founding members of the ALLIANCE. Their experts are member of many international committees (as ICRP, ICRU, IRPA, UNSCEAR, EAN-NORM...). On a national scale CIEMAT collaborates with the regulatory authority in projects related with NORM (pilot projects for NORM industries, coal-fired power plants), ENRESA which is the national company for the management of radioactive waste (NORMIMA project, devoted to the reduction of NORM wastes) or the electrical companies (UNESA), among other.

CLOR: At the moment, there are no ongoing research projects concerning directly aspects of NORM. However, there is the possibility of carrying out tasks within the frame of future international cooperation programs.

GIG: RAMSES: „Monitoring of radium and thallium in the in the vicinity of Mining Sites" bilateral project with IRSN; GIG statutory activity; possible other projects with France and Germany in frame of bilateral cooperation programs

HZDR: TRANSAQUA (national project funded by the Federal Ministry of Education and Research); Research Programme of the Helmholtz Association: Nuclear Waste Management, Safety and Research

IRSN: RAMSES: "Monitoring of radium and thallium in the vicinity of Mining Sites" bilateral project with GIG. Within the framework of the RAMSES project, a PhD has been launched in September 2014 by IPGP, IRSN, CEA and BRGM. This project aims at developing DGT sensors for assessing radium and thallium activities in surface and pore waters along the aquatic continuum (aquifer, rivers and hyporheic zone) together with $^{226}Ra/^{228}Ra$ and $^{205}Tl/^{203}Tl$ isotopic ratios by HR-ICP-MS measurements. These developments will be used for assessing radium and thallium sources in the vicinity of mining sites (including the Polish Observatory sites) and to study the fate of radium through aquatic interfaces (e.g. water/sediment interface, ground and surface water).

IST: ENVIREE (Environmentally friendly and efficient methods for extraction of rare earths elements from secondary sources), ERAMIN international Project: 2015-2017.
- MetroNORM: Metrology for processing materials with high natural radioactivity. EMRP international Project: 2014-2016.
- ROBOSAMPLER- Development of a Terrestrial Robotic System as a Tool for Radiological and Heavy Metal Monitoring in Estuarine Environments funding by QREN/IAPMEI (PORLisboa): 2013-2014.
- COST Action: ES1407 - "European network for innovative recovery strategies of rare earth and other critical metals from electric and electronic waste (ReCreew)", 2015-2017.
- Radiological environmental monitoring programme under Art 35 EURATOM Treaty.

LRA-UAB: The task can be carried out within the frame of a collaboration project that UAB has with phosphate industry and the COST project NORM4Building.

NMBU: There are at present ongoing several national and international projects at CERAD/NMBU addressing NORM both in field and in laboratory studies. The results from these studies will also be made available for the COMET NORM IRA. These projects are funded by Norwegian Research Council, Norwegian Foreign Affairs and also Norwegian Road Construction Authority.

SCK•CEN: The experiments on NORM mobility and availability will be performed within the frame of a PhD project (partially linked with COMET) and by own R&D. Leaching tests will be performed within the frame of the COST project NORM4Building, for FANC (Federal Agency of Nuclear Control) and by own R&D. Soil-vegetation-atmosphere transfer modelling will be performed within a PhD project. The study on gaseous NORM will be performed by own R&D and for NIRAS-Ondraf (national institute for radioactive waste).

STUK: There are no major research projects ongoing at the moment with NORM-related topics, but some information on occurrence and transfer of NORM is gained via environmental surveillance programme and the regulation and monitoring of mine sites. STUK has participated in IAEA-programs e.g. MODARIA, but at the moment the level of participation is rather low. STUK takes part in MetroNORM.

Expected problems, gaps/lack of knowledge, etc. that might prevent the accomplishment of the research

GIG: Lack of financial support.

IST: Lack of national/international financial support to develop the proposed work.

NCSR"D": Lack of financial support (end of contracts).

SCK•CEN: Lack of financial support.

STUK: Reduction of research budget and researchers, which has also lead to reduction in the level of achieved external funding for research.

Human Food Chain

Topical area

The Working Group activities aim to improve radioecological models used in (decision support systems) DSS in Europe, including the inclusion of agricultural practice/production and dietary habit data for different regions. This should lead to improved recommendations of remedial actions and their consequences. In part some of the activities of the WG were initiated, but largely not carried forward, in earlier EC projects (e.g. SAVE, STRATEGY). The WG will learn from the Fukushima and Chernobyl accidents.

The revised ICRP Recommendations state that model predictions should be able to assess the first year dose to humans from all exposure pathways. One important pathway over this time is through the human food chain. The Terrestrial Food Chain and Dose Module (FDMT) as used in Europe within both the ARGOS and RODOS DSS to predict doses from ingestion. One of the deficiencies in FDMT as currently implemented, is the fact that most default parameters (based on German values) may not be appropriate for other regions in Europe.

The focus of the working group over the first 5 years will be the consideration of post-accidental situations in both the short and longer-term. As such the WG will try to learn from studies in Japan following the Fukushima accident (i.e. were there unexpected pathways, how well did models parameterised for European systems work, what parameters/information were lacking in trying to respond to contaminated foodstuffs) and also put these into context with lessons learnt in Europe following the Chernobyl accident.

Were relevant radionuclides associated with, for instance, waste disposal will also be considered. The WG will consider all terrestrial (focussing on agricultural) and freshwater foodstuffs. The WG will not consider NORM radionuclides, nor food products from forest or marine ecosystems as these areas all have dedicated WGs.

Our objectives will be achieved through a combination of experimental/field studies and modelling (sensitivity analyses, testing and improvement). Key strength of the ALLIANCE in being able to achieve this are our wide-ranging expertise, facilities, databases and experience. A number of research topics will be initiated through PhD studentship and our work plan will consequently also contribute to future capacity building. Where appropriate we will align our activities with those of the IAEAs MODARIA follow-on programme to maximise resources, relevance and impact.

Some of the activities discussed below are already on-going/planned in individual member institutes (other key activities are not on-going nor has funding been identified to achieve them), a challenge for the ALLIANCE will be to co-ordinate research activities in a focussed manner and to broaden participation in key research areas.

Leadership

Nick Beresford (NERC-CEH, UK)

Starting date and estimated duration of the WG to accomplish its plan

Starting date: September 1, 2015

Duration of the WG: 5 years

Intended activities (task, approach, steps to accomplish, expected outcomes)

Task 1 Mechanistic and dynamic transfer studies

Process based models of Cs in soil-plant systems have been developed previously (e.g. Tarsitano et al. *J. Environ. Radioact*., 102, 262-9 (which presents an update of the 'Absalom' model)). Using available data on soil properties such models can make spatially explicit predictions of transfer and should be a key tool in post-accident planning. However, studies in Japan following the Fukushima accident are suggesting the underlying models developed in Europe are not optimised to make predictions for all soil types. The further development and testing of such models for Cs, and other radionuclides which may be important following an accident (e.g. ^{90}Sr), should provide a much improved predictive capability, both of radionuclide transfer and also the effects of remediation measures (especially those such as K or Ca fertilisation). Key in the development of process-based models is not to over-parameterise them but to identify, through experimentation and model testing, the key process which need to be parameterised.

A research focus in the next 5 years will be on gaining an understanding of radionuclides (predominantly Cs and Sr) dynamic behaviour in soils (including interaction with water (pore water, vertical leaching to groundwater, horizontal erosion and runoff)), plant uptake (soil-solution-root interface including root exudates and the influence of soil micro-organisms) and deposition (dry/wet deposit, aerosols, plant interception). The overall aim is to identify and characterise key parameters/processes which explain the current high degree of variability in radiological parameters (e.g. K_d, CR). This will reduce uncertainty in parameters used to dynamically describe the transfer of radionuclides between the soil, the soil solution and the roots system of plants and ultimately predicted dose rates to human consumers. This will enable us to propose and develop alternative models that take into account dynamic processes (e.g. chemical speciation, organic matter degradation, sorption/desorption, root uptake and bioavailability). The experimental research will utilize two complementary approaches (a biology-based approach and a chemically-based approach) combining laboratory studies with field experiments including in Europe and areas of Japan and Ukraine impacted by the Fukushima and Chernobyl accidents respectively. We will try to establish why the European models have not worked well in Japan and also utilize this knowledge to improve predictions for European systems.

In addition to the above soil-plant focused studies we will also attempt to identify the K transporters involved in Cs absorption/translocation within plants. We hope to consequently determine the influence of the chemical composition of soil solution (competition with ions, e.g. potassium) on radiocaesium uptake and translocation in plants.

In recent years processes of interception, retention and translocation of radionuclides in plants has been largely unstudied and our models rely upon relatively old parameter values. The Fukushima accident raised question on these issues (e.g. what was the process of contamination of fruit in the first year after the accident). We will conduct experiments, via a PhD project, to investigate these processes for Cs and I (and also Se and Th).

Other studies will utilise members' expertise and on-going programmes to investigate:

- the long-term dynamics of ^{99}Tc, Pu and Am transfer from different soils to crops (studies in the CEZ;
- the long-term behaviour ^{137}Cs and ^{90}Sr in human food chains including investigation of peat soils used as pastures (such pastures continue to be a 'problem' in fSU countries impacted by Chernobyl) and sampling in a number of countries to investigate the derivation of regionally

appropriate transfer parameters (such studies could also provide validation data for any process based models developed);

- the application of ionomics/stoichiometry/phylogeny to determine if data for well-studied elements can be used to make predictions of radionuclides to a wide range of food and forage crops
- the applicability of catchment modelling to predict radionuclides in drinking waters (pilot study in Norway).

In addition to radionuclides likely to be released by nuclear accidents we will also consider some key radionuclides associated with radioactive waste: I, Se, U and Cl. Activities will include:

- testing of processed based models (Pérez-Sánchez &Thorne) of ^{79}Se and ^{238}U-series in soil-plant systems.

Expected outcome: *Improved knowledge of key process determining radionuclide transfer leading to the development of process-based models which should be more widely applicable than existing approaches.*

Task 2 Development of regional parameters

Radioecological modelling is an integral part of advanced European DSS (such as ARGOS and RODOS) for nuclear emergencies. The transfer of radionuclides in food-chain depends on regional characteristics, for instance, agricultural practices and human consumption habits. However, such factors are usually ignored in the current DSS (many being based on southern German data). To allow adaptation of the DSS to local conditions, so called 'radioecological regions' need to be defined and model parameters derived for these. Task 2 of this road map seeks to do this; the activity will in part be started through work package 3 of the COMET project and the EURATOM HARMONE project (due to begin autumn 2015). Required data will be collated from national sources as well as European and FAO statistical data sources. All European areas from Fennoscandia to the Mediterranean will be considered; ALLIANCE members involved in this task have a good geographical spread to enable its success.

Specific soil properties also significantly impact on the transfer of radionuclides, in particular for radiocaesium. In general, highly organic peaty soils with low levels of caesium-fixing clay minerals (e.g. illite), low potassium levels and high concentration of ammonium tend to have higher transfer of caesium to plants than many other types of soil. Studies under Task 1 will develop models taking into account such soil properties and the outputs of this work will be considered here for inclusion in DSS as regionally applicable transfer parameters. Some studies specifically to determine regional specific transfers will also be conducted (see Task 1).

Expected outcome: *Improved prediction of the radionuclide transfer through the human food chain to humans on a regional basis and an enhanced ability to plan and predict the effect of remediation measures.*

Task 3 Remediation measures

A key activity of this task should be to evaluate the remediation measures used following the Fukushima accident and compare lessons learnt with those from the Chernobyl accident to better inform post-accident planning and identify future research needs.

The process based models developed above should be able to predict the impact of soil based countermeasures such as K^+ application or liming. However, such predictions would require experimental validation.

A potential remediation measure previously suggested but rejected from inclusion in handbooks (such as those developed by the EURANOS project) was the exploitation of inter-varietal variation in

radionuclide uptake to replace a variety of a given crop with an alternative variety with a lower radionuclide uptake. This was rejected previously because of a lack of evidence that the approach was feasible. However, recently a meta-analyses of the available data has shown that this approach may be practicable as considerable variation in Cs and Sr uptake exists between varieties of the same crop (Penrose et al. *J. Environ. Radioact*., **139** (2015) 103-117). We will investigate the inter-varietal variation in crop and forage plants to determine if it is possible to select "safe plants".

We will also screen a collection of soil bacteria for their ability to accumulate Sr and/or Cs, and proteins will be engineered to optimize their affinity and selectivity for Sr and/or Cs with the longer term goal of investigating these strains for bioremediation.

Expected outcome: *An improved remediation measures 'toolbox' for Europe.*

Task 4 Improvement of models and Bayesian statistics

The data obtained in previous Tasks, will feed into the improvement of DSS. It is hoped that through participation in programmes such as the IAEAs replacement to the MODARIA programme we will be able to test (and improve) the DSS developed and also widely communicate our activities to increase their impact.

Bayesian statistics

In recent years, the use of probabilistic modelling has generated a substantial interest in deriving more robust parameter values for modelling purposes. In particular, Bayesian methods offer modellers and decision-makers options when faced with a lack of knowledge and data.

The Bayesian Theorem provides a method for modification of probability in the light of new evidence. It allows for both prior knowledge (e.g. generic data) and site-or study specific empirical data to be used. In a food dose assessment model, the use of Bayesian networks could aid the separation of uncertainty and variability in model parameters. Linked to this, the second task will explore how Bayesian statistics can improve the parameterisation of models. Bayesian statistics will be used to estimate probability distributions of transfer parameters and it will also address how we can pool site-specific and generic data. This work has been initiated under the COMET project.

Expected outcome: *Improved parameterisation of models*

Expected problems, gaps/lack of knowledge, etc. that might prevent the accomplishment of the research

Lack of funding, where this is not already in place, and an unwillingness to co-ordinate research activities are likely problems which will need to be overcome if this WG is to be successful.

Partner	Specific interest or contribution
BfS	Provide information on national agricultural practices and dietary habits.
CEA	Mechanistic analysis of radionuclides bioavailability, transfer and/or accumulation in plants, and soil bacteria and algae. Speciation of the radionuclides both in soils and in vivo. Acquire the experimental data necessary for parameterisation of the key processes controlling the transfer of radionuclides. Identification of the transporters involved in the uptake and translocation of radionuclides (Cs) in plants. Determine radionuclide interaction with protein targets leading to accumulation or sequestration, optimization of chelating proteins or peptides (Sr, Cs) for biodetection or remediation.

NERC-CEH	Evaluation of post Fukushima situation including countermeasures. Contribute data from animal studies to IRSN modelling activities. Assessment of varietal variation on forage grass & crop plant uptake (on-going PhD studentship). Testing of SAVE-'Absalom' (or as revised the 'Tarsitano') model (requires funding). Potentially develop alternative models for transfer (under TREE project – progress depends on outcomes of initial plant studies). Could contribute to the provision of regional parameter values as have previously co-ordinated EURATOM projects on this topic (currently no funding for this activity).
CIEMAT	Task 1 Mechanistic and dynamic transfer studies • Understanding and improve alternative dynamic model in soil-plant systems taking into account process of interaction with water (pore water, vertical leaching to groundwater, horizontal erosion and runoff), plant uptake (soil-solution-root interface including root exudates and the influence of soil micro-organisms) and deposition (dry/wet deposit, aerosols, plant interception). • Application of dynamic model to specific radionuclides (Se, U, I, Cl) taking into account the soil properties related to Spanish climate class and regional transfer parameters. • Consider spatial and temporal variability of parameter in process based model as support to identify, through model testing, the key process which need to be parameterised. The activities will include: the development of a semi-mechanistic model for I and Cl; testing of processed based models of 79Se and 238U-series in soil-plant systems. Task 2 Development of regional parameters • Review, update and define regional parameters and characteristics (climate and other regional settings), mainly for the called Mediterranean radiecological regions, but also in another regions in the Iberian peninsula, that will be improved with the knowledge and descriptions of the most representative climate (Cr, Cs, Bs, Bh) and ecosystem (ex. Atlantic, Mediterranean, Steppe) in Spain.
GIG	Minor contribution to the WG – Sr and Cs transfer to agricultural products. Assessment of committed dose taking into account regional customisation of agricultural practices, food production and dietary habit data for different European regions (including specific minorities) – this will be conducted in collaboration with work under the NORM TG.
HMGU	Define regional parameters for human food chain models. Transfer of radionuclides to soil, freshwater and plants by snow and snow melt.

IRSN	Laboratory experiments are ongoing to identify the factors influencing bioavailability for plants and their subsequent translocation fluxes (using Arabidopsis and ryegrass as a plant models). The objective is to determine the role of the chemical composition of the soil and soil solution, bacterial activities, root architecture, organic acid root exudates (e.g. citrates, phytosiderophores), and identification and characterization of membrane transporters responsible for the absorption/translocation of specific elements. In the field, an experimental layout is dedicated to study the transfer of tritium in a grassland ecosystem (fluxes between air, rain water, grass and soil). Field studies also concern freshwater systems, e.g. in Fukushima prefecture (Japan), and terrestrial systems, e.g. in Chernobyl. Compile and analyses data/databases regarding a large range of processes addressing the human food chain (e.g. sorption/desorption in soils and freshwater, root transfer, foliar pathway, transfer to terrestrial and freshwater animal products). Original approaches in data analysis cover: dynamic models, Bayesian statistics, improved categorisation of soils/plant (e.g. based on phylogeny), etc.. Develop SYMBIOSE, an Integrated Environmental Modelling software to include uncertainty/sensitivity analyses and various spatial scales from simple and generic to a complex and site specific landscape-level. Some of this will be achieved through linked PhD studentships.
IST	Mediterranean regional customisation of parameter values to provide predictions on food contamination and consequent doses to humans. Long-term dynamics of soil-to-plant transfers for long-lived radionuclides. Behaviour of caesium during composting of contaminated plant (Alfalfa) biomass. Laboratory small-scale experiment with plants contaminated a) by aerosol deposit, and b) through root uptake. The bioavailability of Cs from detritus will be examined by sequential extraction method in order to distinguish fractions: i) exchangeable, ii) fulvic acid, iii) humic acid, iv) other organic matters
NRPA	Derive parameter values (e.g. transfer, agricultural practices and dietary habits) appropriate for Nordic ecosystems for use in FDMT in ARGOS. Investigate the application of Bayesian methods to derive more robust parameter values in cooperation with IRSN. Continue studies of long-term consequences of the Chernobyl fallout in Norway, including remedial actions. This includes mechanistic analysis of radionuclide (^{137}Cs) bioavailability, transfer and/or accumulation in plants and lichens, and model development. Acquire the experimental data necessary for parameterisation of the key processes controlling the transfer of radionuclides to grazing ruminants (some of this require additional funding) Pilot study on modelling concentrations of radionuclides in surface drinking water after nuclear fallout.

NUBiP	Long-term dynamics of ^{99}Tc transfer factors to agricultural and forest products from different soils under field conditions in CEZ. Long-term dynamic of ^{137}Cs availability in wet peat (soils with extremely high transfers). Long-term dynamics of ^{90}Sr transfer factors to forest products under field conditions in CEZ Region-specific parameters for modelling and countermeasures.
SCK·CEN	Concentrate on mechanistic/process based mobility and bioavailability assessment/prediction and application of countermeasures. Experiments to study the effect of soil-plant remediation measures for specific soil types. We can provide regional data on land use, soil types, dietary habits, hydrology for application in DSS. Set up experiments to derive interception, retention, translocation data for food crops (PhD. studentship 2016-2020). Improve understanding and modelling of soil-to-plant transfer of radiocaesium in Japanese soils (PhD. studentship 2013-2017).
STUK	Development of the terrestrial food chain and dose module (FDMT) used in the decision supporting systems ARGOS and RODOS to predict ingestion doses as well as long term doses from other pathways. Definition and introduction of regional parameter values and habit data into the RODOS. STUK will couple radiation measurements with JRODOS/FDMT to provide them as an input for calculations. The measurements include gamma dose-rate monitoring network results, LaBr3 spectrometer network results, and mobile measurements.
UoP	We are currently working on long term availability of radiocaesium and radiostrontium in ecosystems including freshwater systems. A particular focus is modelling temporal changes in radiocaesium/strontium availability and mobility using long term historical data sets. A further interest is determination of appropriate model complexity using Monte Carlo analysis of sensitivity/uncertainty coupled with analytical methods to determine appropriate dynamic (temporal) resolution of model processes.

Work plan

Planned research activities and time scale: tasks, responsibilities, participants, use of observatory sites, use of large scale facilities, milestones, deliverables, resources committed by partners (estimated man months, in-house funds), requested funds and targeted calls (EC Call, other calls)

Partner	Task	Means	Resources
BfS	Task 2	BfS funds; departmental research projects initiated and supervised by BfS and funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety	5 mm (BfS resources)

CEA		Program Investissement d'avenir (PIA) DEMETERRES, Toxicology program PhD funded by CEA in the framework of the CEA/SCK.CEN project to inventory species living in spent nuclear fuel pools	
NERC-CEH		TREE project; CEH funds	3-4 mm
CIEMAT		CROMERICA, JRODOS, EURANOS manual, BIOPROTA developments	
GIG			
HMGU			
IRSN			
IST	Tasks 1+2		
NRPA	Task 2+4 Task 1 Task 1 – drinking water	COMET NRPA in-kind CERAD projects NRPA in-kind	3 mm 1 mm 3-4 mm 1 mm
NUBiP	Long-term dynamics of TF's of ^{99}Tc and ^{137}Cs	NUBiP	4 mm
SCK·CEN		Regional data (EC HARMONE) Cs behaviour in Japanese soils (PhD funded by Flemish government and SCK•CEN) Interception, retention, translocation project (PhD)-	0.25 mm 48 mm (ends April 2017) 2016-2020 (48 mm)
STUK		JRODOS/STUK	
UoP			

Major elements of the communication plan (workshops, publications, guidance documents…)

Partner	Activity
BfS	Reports, workshops, conferences, contributions to national and international databases
CEA	Referred publications, workshops and conferences, participation to data bases
NERC-CEH	Referred papers, workshops & conferences, liaison with IAEA programmes (currently chair two MODARIA WG's, contributing to SRAS-19 update, contributor to draft 'Comprehensive Fukushima Report'), social media.
CIEMAT	Referred papers, workshops and conferences and liaison with IAEA programmes a Referred papers, workshops, conferences and courses. Liaison with IAEA programmes and ICRP C5. Spanish Platform on Radiation Protection.
GIG	
HMGU	

IRSN	Referred papers, workshops & conferences and liaison with IAEA programmes
IST	Referred papers, workshops & conferences
NRPA	Peer review papers, reports, workshops & conferences, blogging
NUBiP	Referred papers, workshops & conferences
SCK·CEN	Referred papers, workshops & conferences and liaison with IAEA programmes
STUK	Workshops and conferences
UoP	

Links with other activities identified at the national and the international levels

Partner	Link
BfS	BfS projects, national departmental research projects
CEA	DEMETERRES (Development of bio/eco remediation technologies of effluents and soils in support of a post-accident remediation strategy) – coordinated by CEA, co-funded by ANR (French National Research Agency) RSNR call (2013-2018 – 9 m.m/year).
NERC-CEH	TREE project; UK funded PhD.; IAEA programmes; COMET WP3.
CIEMAT	COMET WP3; ICRP C5; UNSCEAR, IAEA (MODARIA); BIOPROTA; PREPARE; JRODOS user group; I+D Committee of the NERIS platform; PEPRI (Spanish Platform on Radiation Protection).
GIG	
HMGU	
IRSN	DEMETERRES (Development of bio/eco remediation technologies of effluents and soils in support of a post-accident remediation strategy) – collaboration with CEA, co-funded by ANR (french National Research Agency) RSNR call (2013-2018 – 9 m.m/year, 1 PhD co-funded) AMORAD project (funded by French gov, same call); COMET/WP3 IAEA programmes (MODARIA) Submitted project HARMONE (OPERRA call) GGP-Environnement (e.g. Modeling of the mid-long term fate of contamination in terrestrial ecosystems. Alternative approaches to Kd) - co-funded by EDF (2014-2016, 12 m.m./year) ACTISOL (influence of siderochelates and phytoionophores on the environmental availability of radionuclides in soils) - collaboration with CNRS, co-funded by NEEDS call (2015-2016, 3 m.m/year) IRSN funded PhD.
IST	C2TN activities
NRPA	CERAD, NRPA activities.
NUBiP	National projects, Ukraine funded PhD.
SCK·CEN	Link with EC HARMONE, FRAME IAEA programmes SCK·CEN funded PhDs

STUK	Part of regular JRODOS update project
UoP	

Marine Radioecology

Topical area

The Fukushima Dai-ichi NPP accident in 2011 has refocused the vision for marine radioecology by highlighting the importance of post-accidental consequences for the marine environment and the limited knowledge that we have in that area. It constituted the most important accidental release of artificial radionuclides to the oceans that has ever occurred. Contamination of every marine component (water, sediment and biota) has been observed. The understanding of contamination levels and radionuclide distributions in the environment, along with prediction of their future evolution requires analyses of detailed monitoring data and the use of modelling tools. In the aftermath of an accidental situation where radioisotopes in the different marine compartments have not equilibrated, time-dependent radioecological models of transfer are required. Such situations offer the opportunity to validate and improve models that are, or have the potential to be, included in decision support systems (DSS) for emergency situations. This post-accidental situation also shows the necessity to develop research on more realistic (and sophisticated) models taking into account trophic transfer process related to pelagic or benthic organisms but also to develop alternative transfer models between dynamic FC and food chain model.

Leadership

Céline Duffa (IRSN, France)

Partners with a brief description of their assigned role

Interested Organisation	Assigned role
IRSN (France)	WG coordination To improve/develop/validate relevant modelling tools liable to account for dispersion of radionuclides (via seawater and sediments) and for transfer of radionuclides to sediments and biota. It is based on: • Improvement and validation of 3D marine dispersion models in French marine areas (Atlantic and Mediterranean seas) by model/measurement comparison ; • Validation of dynamic transfer parameters between seawater and living species by model/measurement comparison over long time series (30 years) (AMORAD project); • Development and validation of sediment transport models by model/measurement comparisons in the English Channel (AMORAD project). • Improvement of transfer parameters between seawater and sediment by taking grain size into account. • Research studies with modelling and *in situ* monitoring on sediments and trophic transfer modelling in Fukushima area (AMORAD project). Part of this new-built knowledge will contribute to develop and validate an emergency modelling tool (STERNE) for marine dispersion and transfer calculations.

SCK (Belgium)	SCK has a major interest for the TWG as evidenced by the work being done currently in the Alliance Marine Group, COMET and the FRAME project and the EC project Harmone. Main focus is on improving the dynamic transfer model D-DAT but with interest also in developing better data for dynamic modelling parameterisation and improved decision support tools, with focus (but not exclusively) on Fukushima, there being other challenges for radioecology (e.g. in the Arctic, Baltic or other environments). Contributions to the challenge: • Ongoing development of the D-DAT marine model by adding new radionuclides, applying locally-derived parameters derived from the FRAME sea cruises in Fukushima and improving its radiological assessment. • Inclusion of the trophic pathway to this model by interconnecting biota compartments with ingestion rates and assimilation efficiencies, and including ingestion of sediments by benthic organisms. • Consider the interactions of pollutant metals and radionuclides • Participate and/or develop, in the international context, biokinetic model intercomparison studies for marine scenarios of interest (link to IAEA MODARIA). • Continue working on the development of allometric approaches for the extrapolation of biokinetic parameters for different biota, radionuclides and heavy metals, including the varying size of the same organisms. • Integration of dynamic transfer modelling methodologies and data into decision support methodologies (link with HARMONE). • Work towards the development of an "advanced D-DAT" modelling package migrating to a FORTRAN platform and developing a user-friendly interface for it.
SU (Sweden)	Detailed field investigation of the role of food web structure in Cs-137 uptake and transfer in benthic food webs, based on new data from a cruise in the Fukushima area in July-August 2015. Possibly ecosystem modelling (depending on future staffing at SU). Continuing contribution to the Alliance Marine Group Possible experimental investigation of uptake of RNs and effects on benthic fauna (in collaboration with other Institutes) – depends on new PhD position.
HMGU (Germany)	Participation in the Alliance working group “Marine radioactivity around Fukushima” Artificial and naturally occurring radionuclides in the Antarctic Ocean seawater and ice will be studied by gamma spectrometry and accelerator mass spectrometry. Valuable additional data for a study of environmental contamination in the Antarctic Ocean area can be expected.
CEA (France)	Contribution to the challenge : Understand the long-term behavior and fate of radionuclides released by Fukushima accident, e.g. sustained concentrations due to ongoing discharges and land runoff by a better and quantitative assessment of radionuclide release from continental source towards the Pacific Ocean in the area of Fukushima. This involves monitoring of radionuclide isotope composition and content in river systems and possibly in clay to silt-sized marine sediment off the estuaries of the coastal rivers draining the main part of continental Fukushima radioactive pollution plume (within AMORAD French project).

UAB (Spain)	FRAME project (also included in COMET Initial Research Activity): • Evaluation of the distribution of radioactive contamination in the various compartments of the marine environment off Fukushima (water column, sediments, biota) and the temporal evolution. • Investigation of the on-going sources from land. • Modelling of future trends.
EPA (Ireland)	Marine Dispersion Modelling • Continuous development and validation of hydrodynamic model of the Irish Sea taking into account transfer factors from seawater to biota and sediments. • Investigate transfer factors from seawater to biota through in-situ monitoring • Investigation of New Build NPP in the UK on the environment through modelling the behavior of potential discharges (both continuous and short term plumes) from the proposed sites, taking into account the various reactor types proposed. • Sensitivity analysis of current marine dispersion modelling tools • Investigate the impact climate change and rising sea levels will have on current and future NPP coastal sites
DTU (Denmark)	Studying long-term behaviour of radionuclides in the Baltic Sea and transfer of man-made radionuclides from Europe to the Faroe Islands and Greenland including dispersion, uptake and modelling
NRPA (Norway)	Dispersion and transfer modelling. Stochastic modelling for simple biokinetic submodels. Sensitivity analysis for the model parameters, especially for the parameters for water-sediment interactions.
NMBU/CERAD CoE (Norway)	Modelling development with higher spatial and temporal resolution will be tested against previous releases from Sellafield (PhD). Development of marine modelling including river and estuarine transport. Implementation of particle codes. Modelling of releases from dumped nuclear submarines in the Kara and Barents seas. Pu and U atom ratios for source characterization (Japan, Kara Sea).
CEH (UK)	Development of REML models for marine biota with NRPA.
CIEMAT (Spain)	Minor contribution (modelling)

Starting date and estimated duration of the WG to accomplish its plan

Starting date: September 1, 2015

Duration of the WG: 5 years

Intended activities

The intended activities contribute to 3 main tasks:

Task 1: Marine dispersion modelling

The task is devoted to development and validation of tools to model marine radionuclide dispersion. It includes knowledge of activity levels in marine areas.

Dissolved or particulate bound radionuclides are concerned in this task.

Approach:
Knowledge of seawater activity trends in different regions (HMGU, IRSN).
Existing hydrodynamic models are used by IRSN. Validation of modelling results is one of the major points of this task. This includes direct measurement of physical parameters (currents, salinity…) and use of existing radiotracers (already proved to be valuable tools for the improvement of radionuclide dispersion models, in the English Channel and the southern North Sea), Inputs of tritium from French nuclear power plants (via Loire and Gironde estuaries) will be used to perform similar validation in the gulf of Biscay, by using ultra-low level measurements of dissolved tritium (HTO). NMBU/CERAD will also validate model development (improved resolution) using existing data from Sellafield releases into the North Sea, as well as dispersion within Kara Sea and Barents Sea associated with sunken submarines (collaboration with NRPA).
NRPA uses box modelling approach for the Baltic Sea and Fukushima coastal waters with regards to accidental releases. This box approach uses non-instantaneous dispersion of radionuclides in seawater where sea region is "open" for dispersion after some time after accident (time of availability).
Implementation of sediment transport model to hydrodynamic modelling is included in this task.
IRSN will perform this model connection for some case studies.

Steps to accomplish:
IRSN will perform measurements of tritium concentrations French coastal areas, together with other tracers (salinity) and physical parameters and model/measurements comparisons. In situ measurements of particulate matter and of different parameters to calibrate and validate locally sediment transport models.
NRPA will make sensitivity analysis for the model parameters, especially for the parameters for water-sediment interactions.
NMBU/CERAD will improve the model resolution, and implement particle codes.

Expected outcomes
Validated dispersion model relevant for normal or accidental discharges from nuclear plants or ship wreckage, usable in DSS or for post accidental studies.

Task 2: Radioecological transfer in marine environment

This task includes modelling and experimental studies (to quantify transfer parameters or to study specific processes).

- 2.1 Transfer to biota

Approach:
Estimation of dynamic transfer parameters between seawater or sediments and biota.
Use of available time-series of radionuclide concentration obtained in-situ (IRSN will use data from the Channel, in the vicinity of the release point of the reprocessing plant of La Hague), or specific experimental study.
Use of dedicated experimental studies for pelagic or benthic species (SU).
Implementation or validation of existing models (including results already obtained during Initial Research Activity) (SCK, IRSN, NRPA).
Test models based on taxonomic groupings (CEH).

Steps to accomplish:

Existing FC and Tb data compilation (direct link with IRA).
Define experimental studies to perform and the experimental procedures.
Use of allometric approach for extrapolation of biokinetic paramaters (SCK, CEH, NRPA).
Improvement or extension of existing dynamic transfer models (SCK, IRSN, NRPA).
Sensitivity analysis.

Expected outcomes:
Documented database of dynamic transfer parameters for an extended list of radionuclides and marine biota.
Radionuclide dynamic transfer modelling to marine biota with implementation of the trophic pathway in parallel with the seawater pathway.

- 2.1 Transfer to sediments

Approach:
Development and validation of dynamic models instead of simple Kd use by Implementing or improving radionuclide transfer to the sediments modelling.

Steps to accomplish:
Deriving operational relationship between radionuclide concentration (and Kd) in sediments and particle grain-size (IRSN).
Improving of kinetic transfer parameters using model/measurements comparison (IRSN, SCK).
Sensitivity analysis (NRPA).
Implement estuarine processes, and Improving Pu atom ratio database (NMBU/CERAD)

Expected outcomes:
Use of more realistic transfer parameters for modelling the dispersion of sediment-bound radionuclides.

Task 3: Fukushima case study

This task aims to have a better understanding and estimation of the long-term behavior and fate of radionuclides released from Fukushima station.

Approach:
Examination of available activities time series for every compartment (seawater, sediments, biota).
Dedicated studies and projects including *in situ* measurements and samplings in rivers, estuaries and sea (oceanographic cruises). These studies' results will improve our knowledge and understanding of the contamination state and evolution. FRAME and AMORAD projects are directly linked to this task.
Investigation of the inputs from land (from rivers or from underground water).
The transfer to biota will be one of the main research challenges, especially for the benthic species.

Steps to accomplish:
Evaluation of the distribution of radioactive contamination in the various compartments of the marine environment (water column, sediments, biota) and the temporal evolution (UAB, SCK, IRSN, CEA).
Design and validation of erosion models to estimate impacts of land use change / rainfall scenarios on radionuclide export from Fukushima coastal catchments to the ocean (CEA).
Estimation of the land ^{137}Cs inputs contribution to the ongoing contamination of the coastal area (IRSN).
Measurements of $^{240}Pu/^{239}Pu$ ratios for source identification (NMBU/CERAD).

Design of sediment un-mixing models based on plutonium isotopic ratios (e.g. $^{241}Pu/^{239}Pu$ ratio) to calculate spatial and temporal variations of this radionuclide redistribution (CEA).
Evaluation of pathways of trophic transfer in benthic food webs, through collection of new field data from Fukushima benthic coastal ecosystems (SU).

Expected outcomes:
Better understanding of the post-accidental situation and possibly evaluate future trends. Improvement of knowledge concerning radioecological transfer processes.
Test and validation of existing or developing radioecological models (this task constitutes one case study for task 1 and 2).

Work plan

Partner	Concerned tasks	Means, fundings	Resources
IRSN	Coordination Task 1 Task 2 Task 3	T1: IRSN, Marine IRA T2: AMORAD T3: Marine IRA, IRSN PhD 2016-2019	T1: 36 man.months (PhD) T2: 72 man.months T3: 72 man.months
SCK	Task 2	FRAME project, Marine IRA	3.75 man.months
SU	Task 2 Task 3	SU PhD funding SU own funds	12 man.months 3 man months
HMGU	Task 2 Task 3		4 man.months
CEA	Task 3	AMORAD CEA PhD funding (36 months)	20 man.months
UAB	Task 3		
EPA	Task 1		
DTU	Task 1		
NMBU	Task 1 Task2 Task 3	CERAD (PhD), Bilateral Norwegian – Russian projects	18 man.months 6 man.months 2 man.months
NRPA	Task1 Task2	EFMARE (NKS project); CERAD (Norwegian program) PREPARE	14 man.months
CEH	Task 2	TREE	1 man.months

Cited projects:

AMORAD (Improvement of radionuclides dispersion and impact assessment. modelling in the environment), 2013-2019 – supported by ANR (French National Research Agency),

CERAD is a Norwegian center of excellence for environmental radioactivity, established at NMBU

EFMARE (Effects of dynamic behaviour of Nordic marine environment to radioecological assessments) supported by the Nordic nuclear safety research (NKS).

PREPARE (Innovative integrated tools and platforms for radiological emergency preparedness and post-accident response in Europe, http://www.prepare-eu.org/), supported by EU commission.

TREE (Transport, Exposure, Effects, http://www.ceh.ac.uk/tree)

FRAME (The impact of the recent releases from the Fukushima nucleaR Accident on the Marine Environment), COMET supported project (2014 call).

HARMONE (Harmonising Modelling Strategies of European Decision Support Systems for Nuclear Emergencies – an OPERRA project).

Major elements of the communication plan (workshops, publications, guidance documents…)

IRSN	COMET meetings, workshops, conferences, publication in international journals
SCK	COMET meetings and workshops, conferences, publication in international journals
SU	International conferences, publication in international journals, teaching
HMGU	publication in international journals, workshops
CEA	International workshops (EGU Vienna, AGU San Francisco,…) Publications in international journals
UAB	Publications under FRAME project
EPA	
DTU	
NMBU	Refereed publications, International conferences
NRPA	International conferences, publication in international journals, PhD
CEH	Refereed publications, conferences and workshops

Links with other activities identified at the national and the international levels

IRSN	AMORAD (French National Agency Project 2014-2019)
SCK	FRAME
SU	Collaborations with TUMSAT, Hokkaido University and Fukushima University (Japan), CERAD (Norway)
HMGU	
CEA	AMORAD (French National Agency Project 2014-2019)
UAB	FRAME
EPA	
DTU	
NMBU	CERAD, Bilateral Norwegian – Russian collaboration, Prepare
NRPA	EFMARE, PREPARE, CERAD
CEH	TREE

Expected problems, gaps/lack of knowledge, etc. that might prevent the accomplishment of the research

- Organization and funding of cruises to collect marine samples.
- Access to environmental description data concerning Fukushima marine area.
- Accessibility to marine ecosystem trophic chain description, especially benthic ecosystem.
- Difficulty to sample clay- to silt-sized sediment in marine environments (dominance of coarse material off the estuaries in Fukushima).
- Difficulties to match models and data when data is not of the type or in the form needed by the models.

Transgenerational Effects and Species Radiosensitivity

Topical area

The issue of biological effects of low doses of ionising radiation along with the 'hot question' from the public/media on the potential hereditary effects for both humans and wildlife is of major concern. This has been reinforced after the Fukushima accident, especially with respect to the quantification (and reduction if needed) of the magnitude of risk to individual (human) and population (human and biota) health when exposed at low doses/dose rates for multiple generations. This concerns both chronic exposure over several generations, and intermittent exposure (e.g. consequences of a short exposure in one generation to the others). The challenge is clearly to improve our understanding of the cascade of responses, from primary interactions of ionising radiation with biomolecules to adverse outcome for physiological functions, including reproduction, and ecosystem function.

Addressing the issue of biological consequences induced by low doses, we need to improve our knowledge on **long term and transgenerational effects**. This includes the study of genetic changes (mutations) but also the role of epigenetic mechanisms, both determining the adaptation ability of organisms. In particular, the role of epigenetics in genomic instability and inheritance in organisms/cells exposed to radiation/radionuclides and also in adaptation of organisms under conditions of a pressure selection must be better understood. In perfect complementarity, mutation rates and types are to be assessed and quantified in parallel. This will enable distinguishing between epigenetic and genetic induced changes.
The second topic of interest in this working group deals with differences of **radiation sensitivity** across species and phyla are poorly understood, but have important implications for understanding the overall effects of radiation and for radiation protection: sensitive species may require special attention in monitoring and radiation protection; and differences in sensitivity between species also lie behind overall effects at higher levels (community, ecosystem), since interactions between species will be altered. Understanding the mechanisms of inter-species radiation sensitivity may also help us understand mechanisms behind intra-species variation.

Leadership

Christelle Adam-Guillermin (IRSN, France) and Nele Horemans (SCK CEN)

Partners with a brief description of their assigned role

Interested Organisation	Assigned role
IRSN/Laboratory for radionuclide ecotoxicology, Christelle Adam-Guillermin (France)	WG coordination Use of (epi)genomic, transcriptomic and/or proteomic data to identify fingerprints/key processes, genes involved in transgenerational effects and radiosensitivity such as adverse hereditary or adaptive effects, induced by ionizing radiation (gamma, alpha irradiation, tritium) • role of genetic and epigenetic mechanisms in transgenerational effects, for 1 to 4 generations

	exposed under laboratory controlled conditions to ionizing radiation (in zebrafish, nematodes, daphnids) • role of genetic and epigenetic mechanisms in adaptation mechanisms, for 20 generations exposed under laboratory controlled conditions to ionizing radiation (nematodes) • study of organisms isolated from radionuclide contaminated sites (Chernobyl, Fukushima) to study resistance/adaptation mechanisms (nematodes) ; same goal but studying structural parameters of soil ecosystems (nematode species composition) • characterization of biomarkers of ionizing radiation effects from laboratory and field (frogs, birds) • role of protein carbonylation in transgenerational effects, adaptation and radiosensitivity : comparison of acute vs chronic data (nematodes, zebrafish) • comparison with other stressors (chemicals Evogenerate SETAC group, natural stressors) ; natural variability • role of metabolism in transgenerational effects, adaptation and radiosensitivity : use of Dynamic Energy Budget (DEBtox) models • comparison of environmental protection criteria obtained from one generation vs several generations
Helmholtz-Zentrum Dresden – Rossendorf, Karim Fahmy (Germany)	• In combination with genetic analyses and genetic engineering, the acquired data allow identifying genes that are critically involved in radionuclide-resistance and are prime candidates to identify transgenerational effects and radiosensitivity. • Real time monitoring of low dose radiation responses using metabolic heat measurements in bacterial cultures and multicellular organisms. • In combination with the isolation of model organisms from radionuclide-enriched sites, the research activities at the IRE provide quantitative reference data on radio- and chemitoxicity at low doses that can be directly related to molecular mechanisms that are under genetic control. • Adaptive effects will be revealed for microbial isolates from mining waste piles. The establishment of low dose-responsive model organisms and the molecular understanding of

	particle energy-dependence of biological effects will lay an important ground for defining knowledge-based radiation risk assessments and protection standards in radioecology.
Ukrainian Institute of Agricultural Radiology (UIAR), Valery Morozova (Ukraine)	The goal of our research work is to get the "dose-effect" dependence to develop approaches of the environment protection from radiation. Results will be obtained on the basis of the scientific monitoring of the radiobiological effects of the chronic ionizing radiation on the reference plant species (Arabidopsis and Scots pine) in the areas radioactively contaminated by Chornobyl NPP under the different levels of external and internal exposure. These results will allow the improvement of understanding of the mechanism of the organism adaptation to ionizing radiation. Besides it, future results will contribute to improve the number and quality of reliable protection criteria for ecosystems and their sub-organisational levels with respect to exposure to radioactive substances. These criteria are needed to support emerging policy in the field of radioprotection of the environment per se as this is now explicitly mentioned in both the International Basic Safety Standards (BSS) from IAEA, and the updated EURATOM BSS. • study of the functional state of the cell antioxidant defense system of the leaves and roots of Arabidopsis (Arabidopsis thaliana) and needles of Scots pine (Pinus sylvestris L.) and tissues of the sprouted in the laboratory seedlings of these plants. • estimation of morphological changes in plant samples. • cross comparison with the results of similar researches under the laboratory conditions.
NERC Centre for Ecology and Hydrology Molecular Ecotoxicology and Ecotoxicology Group, Dave Spurgeon (UK)	Study of the epigenetic and transgenerational effects of chemicals. From the projects we are running, we will have a growing set of working analytical and bioinformatic tools available for looking at transgenerational and epigenetic effects. • using next generation sequencing to map changes in the epigenome to expression change. • run transgeneration experiments for a range of chemical exposures (PhD). • study of epigenetic changes in earthworms in the field (Chernobyl) (European project Comet) and of transgenerational gamma effects (PhD). The two PhDs are collaborative with Prof. Peter Kille in Cardiff who has the expertise in the

	design and analysis of next generation sequencing for various type of assessment (RNAseq, RAD-seq, bisulphide etc.)
NERC Environmental Contaminants Group Centre for Ecology & Hydrology CEH Lancaster, Nick Beresford (UK), Jan Baas	Involved in TREE Program (NERC) with different research axes • data obtained from more than 40 wildlife trap cameras in Chernobyl could be used to model abundance of medium-large mammals in three study areas (TREE work in collaboration with Salford University); • study of ionizing radiation effect on feather hormone (PhD starting in October in collaboration with Christelle Adam IRSN) • study of soil functional parameters, like turnover processes, by using bait laminae in CEZ this year • use of dosimeters/GPS set on mammals in CEZ from next spring for better dose estimates. Use of these data for better characterization of dose-response curves (*both WGs*). • DEBtox modeling incorporating the metabolic rate
University of Portsmouth, School of Earth and Environmental Sciences, School of Biological Sciences, Adélaïde Lerebours (UK)	The research aims at studying the effects of low doses of ionizing radiations on natural populations of fish from the CEZ. This work could contribute to a better understanding of the molecular and physiological changes in fish induced by radiation exposure and the identification of relevant biomarkers for the effects of radiation. Specifically, the work is focusing on long-term consequences of radiation exposure on the reproduction of fish. • The consequences of parental gonad exposure to low doses of radiation will be investigated by examining the early life stages of their offspring. This will highlight the significance of transgenerational effects. • In parallel, our laboratory experiments aim to determine the effects of low doses of ^{32}P exposure on gonads and early life stages of the 3-spined stickleback. The work include biometric, histological, genotoxicity and transcriptomic analyses.
Russian Institute of Radiology and Agroecology, Laboratory of Plant Radiobiology and Ecotoxicology, Stanislas Geras'kin (Russia)	• Cytogenetic effects, isozymes polymorphism, enzymes activity, morphological and reproductive characteristics in chronically irradiated Scots pine populations inhabiting sites contrasting in level of radioactive contamination within Bryansk Region of Russia and Poleski

	Radioecological Reserve of Belarus will be estimated. • effects in natural populations and levels of technogenic impact as well as meteorological conditions will be performed • Analysis of relationships between manifestation of biological; time-dynamics and ecological-genetic variability in irradiated populations will be studied • the role of antioxidant enzymes in adaptation of plants to chronic influence will be estimated
SCK•CEN, Biosphere Impact Studies (BIS), Nele Horemans (Belgium)	Study of possible long-term or transgenerational effects of ionizing radiation on plants. • Epigenetic mechanisms leading to long term and transgenerational changes induced by low-dose radiation is being studied in two plant species (Arabidopsis and Lemna). • Additionally we are interested in mechanistically analyse if long-term exposure of plants to above background levels of radionuclides like U will induce an altered tolerance or sensitivity of the plants to the radionuclide it is being exposed to or to an alternative stressor. • This includes also priming experiments where plants are exposed to e.g. a low concentration of U or gamma radiation and the effect of a subsequent exposure to the same or other stressor is studied within the same generation or over several generations. • *On the topic of Radiosensitivity - SCK•CEN could in future contribute to study the functional mechanisms leading to radiosensitivity in plants. This will be accomplished by comparing the molecular profile and the regulation of the molecular mechanisms in at least two molecular model plant species (Arabidopsis thaliana and Oryza sativa) differing largely in radiation sensitivity and at different life stages of the plant. In addition these data can contribute to a larger comparison of interspecies sensitivity.*
Gent University, GhEnToxLab, Karel De Schamphelaere (Belgium)	• We could mainly contribute with bioinformatics of whole genome bisulfite sequencing data; with daphnia or other organisms. • Possible contribution to transgenerational effects part with Daphnia omics in general, and gene expression (whole genome transcriptomics) and genome wide DNA methylation (methylome) specifically.

	• *We are also interested in variation of responses between different daphnia species, between daphnia clones (within species) and between different populations (e.g. living in historically impacted environments).* • We are also interested in combined stress (e.g. U both as a toxic metal and at the same time resulting in radiation exposure, or radiation in combination with other chemical stressors).
Stirling University, David Copplestone (UK)	Study of long-term & transgenerational effects of ionizing radiation on insects (bees, drosophila) freshwater microcrustacean (daphnids), birds in the laboratory and in the field (Tchernobyl)
CEA, Laboratory for cellular bioenergetics, Laurence Blanchard, Arjan Degroot (France)	Study of long-term effects of ionizing radiation on bacteria : investigation of toxicity and resistance mechanisms
Norwegian University of Life science, (Deborah Oughton (Norway)	Study of long-term & transgenerational effects of ionizing radiation on worms (nematodes) and fish (zebrafish, in the laboratory (Co-60 irradiator) and in the field
GIG, Bogusław Michalik (Poland)	Study of transfers and dose characterization

Starting date and estimated duration of the WG to accomplish its plan

Starting date: April 2016

Duration of the WG: 5 years

Intended activities (task, approach, steps to accomplish, expected outcomes)

The intended activities contribute to the understanding of transgenerational and long-term effects, including resistance/adaptation effects, in three main tasks :

The work described here aims is focusing on the use of (epi)genomic, transcriptomic and/or proteomic data to identify fingerprints/key processes, genes involved in transgenerational effects such as adverse hereditary or adaptive effects, induced by ionizing radiation (gamma and alpha irradiation, tritium, ^{32}P, U) in the laboratory or in the field.

Approach:

Task 1 B**iomarkers of transgenerational/adaptation effects** : laboratory (and possibly field) studies will be undertaken to identify genes/proteins/epigenetic marks that are critically involved (i) in transgenerational effects or (ii) in radionuclide-resistance, and are prime candidates to identify transgenerational effects. Experiments will be performed in the laboratory on three-spined stickle bass (UoP), zebrafish, nematodes, daphnids (IRSN), Arabidopsis and Lemna (SCK•CEN), Scott pines (RIRA), bacteria (HZD and CEA).

The role of anti-oxidizing compounds (RIRA) and protein carbonylation (IRSN, CEA), will be specifically investigated. A system biology approach will be used to integrate the biological responses.

The acquired data will be integrated in population dynamics models, allowing a comparison of protection thresholds for the individuals or the population levels.

Task 2 Radioadaptation : priming experiments will be performed by exposing organisms to a low dose; the effect of a subsequent exposure to the same or another stressor will provide knowledge in physiological adaptation within the same generation or over several generations (SCK•CEN, IRSN). Adaptation will also be studied by exposing several generations to dose rates acting as a selection pressure in order to better understand the (epi)genetic main actors of selection/adaptation/resistance mechanisms. Organisms isolated from field situations (e.g. mining area, Fukushima and Chernobyl Exclusion zone) will also be used to study resistance/adaptation mechanisms (nematodes (IRSN), bacteria (HZD), Scott pines (RIRA, UIAR), Arabidopsis (UIAR, SCK•CEN).

Transgeneration/adaptation mechanisms will also be studied in populations and ecosystems by characterizing effects of ionizing radiation on natural populations exposed in situ. This will include the study of structural changes of soil nematode (IRSN), earthworms (CEH, NMBU) and medium-size, large mammals populations (CEH). It will also include the study of functional changes of soil ecosystem by the use of bait lamina (CEH) and of plant communities (UIAR and RIRA).

Task 3 Role of metabolism in transgenerational/adaptation effects : the metabolic activity of cells and organisms can provide a highly reproducible biological signature of radiation effects (studied in bacteria at HZD). This approach could be applied to other organisms and be directly used in a DEBtox model to infer on the possible role of metabolic activity in transgenerational effects.

Steps to accomplish

Tasks 1 and 2 integrate within the framework of COMET WP4 Initial Research Action, dedicated to understanding the role of epigenetic mechanisms in transgenerational effects. As such, deliverables from this COMET WP4 will serve as basic information to better define future work to be accomplished. This will drive to write a position paper in 2016 to give guidelines on how to perform transgenerational studies taking into account genetic and epigenetic effects. In addition to these guidelines, a rationale for performing such studies will be given, integrating the major factors or key questions to take into account (e.g. specificity of biological functions or biomarkers of effects, dose-effect relationship if any, core of conserved mechanisms among biological models or specific genes/proteins explaining radioadaptation). From this paper will possibly come out a common project to be submitted to a European call for proposal, in collaboration with the other platforms (e.g. CONCERT second call in 2017). A specific pilot study could also be designed to answer an explicit biological hypothesis.

Several guidelines could be written : guidelines for setting up laboratory experiments with specific objectives and this for all the model species ; guidelines for conducting field experiments and given specific aims ; guidelines for specific analysis (gamma H2 AX, methylation grade) in order that people wanting to do the same work, applying the same techniques do not have to go through the same pitfalls.

In addition, a literature review and knowledge exchange will be performed among partners to better identify the common basic knowledge on transgenerational/radioadaptation effects, acquired even in acute exposure conditions or in the toxicology field. This approach will enable to identify candidate genes or processes for the context of radioecology in the chronic low dose context and will allow a better characterization of research needs.

Another action could be focused on the study of dose-response relationships. In the FREDERICA database, build under the European project ERICA (6th FWP Euratom) and gathering all referenced effect studies, there are several datasets on mutational effects and other molecular level endpoints. These data could be further analysed in order to try to better define the range of dose rates by which such molecular responses are observed, for each considered organism. This will probably lead to define a benchmark based on this type of mutational response, that would be useful to interpret several in situ date. The shape of the curves could be studied, trying to identify the relevance of linear-models for these low dose rates range. Furthermore, these analyses could help in defining the term “low dose” for non-human species. This outcome would be a great step towards the integration of molecular responses in the regulatory framework, and would help to better define radiological protection criteria for non-human species.

Expected outcomes

The work accomplished in these three tasks will result in a better identification of radio-induced effects for the context of chronic low doses of exposure, highly relevant for natural sites and their non-human inhabiting species, for contexts such as routine radioactive discharges, high background natural radioactivity area and post-accidental conditions. Along with this knowledge, a better characterization of natural variability will be possible in wild organisms challenging highly variable nutrition, predation, multipollution.

Some specificities of the dose-responses in these conditions will be investigated through modelling approaches (non-linear dose-response curves, hormetic responses).

The intensity of biological responses induced by ionizing radiations will be compared with other pollutants such as metals by favouring collaborations with ecotoxicologists (e.g. through the evogenerate SETAC working group).

From a regulatory perspective, the understanding of low dose effect relationship will help to derive environment protection criteria.

In addition to these scientific outcomes, this working group will contribute to knowledge dissemination, in terms of workshops, student exchanges, shared experiments and platforms.

Work plan

Planned research activities and time scale: tasks, responsibilities, participants, use of observatory sites, use of large scale facilities, milestones, deliverables, resources committed by partners (estimated man.months, indoor funds), requested funds and targeted calls (EC Call, other calls)

Partner	Task	Means	Resources

IRSN, SCK•CEN, NERC CEH, NMBU, Stockholm Univ. …	Coordination Task 1 : paper position from COMET WP4 Task 2 : guideline on field studies Task 3 : DEBtox modelling integrating metabolic rate	T1 : COMET WP4 T2 : Ecorad ? (Biodiversa) CONCERT 2nd call T3 : DEBtox	T1 : 24 MM (post-doct), 72 MM PhD (2015-2018 ; 2016-2019) T2 : in function of project selection 24 MM (post-doc)

Major elements of the communication plan (workshops, publications, guidance documents…)

Partner	Activity
IRSN	COMET meetings, workshop, publications in peer reviewed journals, guidelines, share PhD students, sterring committee of PhD ? Position paper

Links with other activities identified at the national and the international levels

Partner	Activity
IRSN	COMET WP4 (epigenetics on zebrafish, nematodes, and in situ on frogs & birds). Contract with Electricité de France on low dose effects (tritium and gamma external irradiation). National research programs on epigenetics (NEEDS). IRSN research programs on low dose effects. 2 PhD and 1 post-doc on epigenetics changes induced by ionizing radiation.
HZ-IRE	Research Programme of the Helmholtz-Gemeinschaft: Nuclear Waste Management, Safety and Radiation Research
UIAR	COMET WP4, national project NUBiP of Ukraine No. 110/72f
NERC CEH MEEG	Working on two projects on the epigenetic and transgenerational effects of chemicals. One has been using next generation sequencing to map changes in the epigenome to expression change. The second is running transgeneration experiments for a range of chemical exposures. Also new PhD project on epigenetic changes in earthworms in the field due to start. Work in Comet on transgeneration gamma effects on earthworms. The two PhDs are collaborative with Prof. Peter Kille in Cardiff who has the expertise in teh design and analysis of next gereation sequencing for various type of assessment (RNAseq, RAD-seq, bisulphide etc.)
NERC CEH CG	TREE Project (see in partners description section)
UoP	Transfert Exposure and Effects project (NERC funded).
SCK•CEN	COMET WP4

Ugent	AquaStress project: we have one pH d student working on multigenerational effects of metals and heat stress (simultaneous and sequential exposure)
RIRA	Russian Scientific Foundation (grant 14-14-00666) Analysis of adaptation mechanisms in plant populations to technogenic impact
Stirling Univ	
CEA	
NMBU	
GIG	

Expected problems, gaps/lack of knowledge, etc. that might prevent the accomplishment of the research

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Atmospheric Radionuclides in Transfer Processes

Topical area

The Fukushima accident has highlighted several lacks considering air transport and inhalation dose assessment, deposition stage from atmospheric releases or long-lasting secondary emissions from previous deposits. Inhalation dose assessments have suffered from the relatively low-number determinations related to the gaseous iodine contribution. Attention should also be paid on the health effects of the particles, based on their size distribution, composition, crystalline structures, oxidation state influencing weathering rates and solubility in soil-water and sediment-water systems. Adachi et al. (2013) have found highly cesium-labeled airborne particles up to 2.7µm far (180 km) from the damaged NPP. Information on the source term and release scenarios is essential as input to atmospheric transport, and particle codes should be implemented in transport models. Regarding atmospheric processes, some peculiarities of winter time meteorological conditions such as snow and fog events have shown to be responsible for additional radionuclide deposition in some parts of the northern rim of the Kanto plain, Japan (Hososhima & Kaneyasu 2015). The European situation is not very different from that of Japan both regarding the current capability to attest for a gaseous contamination and specific wintertime meteorological conditions. Such conditions would provide the same interactions of snowflakes or fog droplets with radionuclide-labeled aerosols in case of an accident release. Finally, the long lasting post-accident stage would be also characterized by secondary emission through resuspension, biomass burning and biogenic aerosol production that remained to be fully understood despite some preliminary works performed after the Chernobyl accident.

Leadership

Olivier MASSON (IRSN, France) and Jochen TSCHIERSCH (HMGU, Germany)

Partners with a brief description of their assigned role

Interested Organisation	Assigned role
IRSN (France)	WG coordination; Field experiments on fog deposition, secondary emissions of biogenic aerosols; Improvement, test and validation of gaseous sampling/measurement aimed at lowering detection limits ; Reference size distributions for low level anthropogenic radionuclides; Atmospheric ^{210}Po baseline.
HMGU (Germany)	WG coordination; Field experiments on snow deposition; Model implementation of deposit and release of winter time contamination; Retrospective size determination; Parameterization of deposition/resuspension processes for post accidental forecast; Tracing of hot particles after the Fukushima accident.

CERAD (Norway)	Characterization of radioactive particles released from a series of different sources. Implementing particle codes and characteristics (particle properties) in air transport models. Linking particle characteristics to weathering rates/solubility using extraction techniques. Testing cascade impactor in contaminated areas. Modelling of air transport and deposition of particles.
CIEMAT (Spain)	Field experiments on resuspension using time series of radionuclide contents in soils/air; Study of $^{239}Pu/^{240}Pu$, ^{137}Cs, ^{226}Ra ^{210}Pb, ^{210}Po and U fluctuations in air particles; Study of Pu sources in air through their isotopic ratios, and retrospective analysis;
NCSRD Demokritos (Greece)	Monitoring of ambient levels and size distribution of radioactive tracers in the atmosphere. Studies of submicron radioactivity as tracers for atmospheric processes; Field testing and development of methods for size resolved aerosol radioactivity; Seasonal variability and long range transport of natural and anthropogenic radionuclides in the Eastern Mediterranean; Studies at high altitude and ground atmosphere; Wet scavenging and deposition.
SCK-CEN (Belgium)	Based on field experiments on snow deposition and the model simulations, sensibility and uncertainty analysis of the parameters and models involved in the research. Definition of strategies for conceptualization, calibration and validation of models for different scenarios with focus on key parameters identified after the sensitivity and uncertainty analysis.

Starting date and estimated duration of the WG to accomplish its plan

Starting date: September 30, 2015

Duration of the WG: 5 years

Intended activities

The intended activities contribute to 4 main tasks:

Task 1: Deposition

This task is devoted to the definition of relevant range of values that makes it possible to characterize the importance of fog deposition, snow deposition, dry vs. wet only deposition in order to prioritize and assess deposition mechanisms according to meteorological conditions. It includes knowledge of activity levels in the air (total particle content as well as according to various particle size ranges) and in water (snowflakes, raindrop, fog droplets). In Japan, it has been recognized that locations that showed significant differences between deposition computations and field observations had encountered snow or fog. This finding highlights 1) the contribution of such events to ground contamination and 2) that models do not specifically take them into account. Very recent observations confirm the high radionuclide deposition potential of fog events on vegetation on a yearly basis for frequent foggy locations) compared with annual rain deposit.

Particle size range is also of main importance with regard to the deposition velocity of radionuclide-labeled aerosols. It has also a great importance on inhalation intake and subsequent dose assessments.

Approach: Mostly based on field experiments and when possible on laboratory experiments to fix the analytical values for microphysical parameters in controlled conditions. Parameters shall be useful for implementation in existing decision support systems.

Steps to accomplish:

- at IRSN: Study on rainout process based on fog/cloud deposition of gamma emitter radionuclides and Tritium on plants. Size distribution of radionuclides in normal situations as reference values.
- at NCSRD Demokritos: Study on wet only vs. dry only deposition of radionuclides. Size distribution of radionuclides.
- at HMGU: Study on snow deposition of radionuclides and its implementation in forecast models. Retrospective size distribution from nebulization of filter solutions.
- at SCK•CEN : definition of strategies for conceptualization, calibration and validation of models for snow deposition of radionuclides based on sensitivity and uncertainty analysis.

Outlook:
Future step will concern tritium deposition by fog and cloud. Surface deposition on various kinds of vegetation (roughness, leaf area index) will be investigated based on a large variety of plant. The determination of deposition velocities will be assessed through different innovative method (to be tested) including Particle Image Velocity (PIV) and deposition flux by eddy correlation and compared with classical approach (mass measurements).

Refinements will also concern the characterization of snowflakes according to micro-physical parameters including different shape descriptors of the hydrometeors. Proposals will be developed to improve parameterization in existing decision support systems for a better forecasting of deposition in emergency situations.

Expected outcomes
All these knowledge will be aimed at filling lack of knowledge with respect to meteorological conditions (e.g. winter scenarios with snow and fog) we could experience in Europe, providing typical range of operational values for relevant parameters (rainout, washout and snowout coefficients, deposition flux and velocities, collection efficiencies) during routine or incident/accident situations.

Task 2: Gaseous species

This task concerns improvement of various steps from sampling to measurement in order to lower the detection limit of gaseous species that represent most of the total (gaseous + particulate content) as for iodine. The iodine gaseous fraction remains usually predominant but still suffers from high detection limits (about 100 – 1000 times that for the particulate fraction). After the Fukushima accident the number of gaseous samplings was only about 20% of that for aerosol in Europe. Even if the consequences of the Fukushima accident was of no concern for public health in Europe It can be asked on the reliability of dose assessment when 80 % of the concentration is missing. According to dose coefficients (ICRP 71), it can be demonstrated that including gaseous iodine (I_2 or CH_3I) to particulate iodine in inhalation dose assessment will multiply the inhalation dose by a factor of 10 to 20 depending on the gaseous species considered.

Apart from severe accident releases, some recent incidents (November 2011, February 2012, March 2015) in Europe were responsible for large scale spreading of ^{131}I traces on the European scale. It is known that iodine is volatile and remains predominantly in its gaseous form in the atmosphere. However, the ratio gas/particle remains difficult to assess and then any attempt in inhalation dose assessment will be inevitably associated with large uncertainties. Moreover existing gaseous sampler are rarely equipped with heater that could lower the competition between iodine and water vapour. This may lead to underestimation. Further improvements, such as gaseous speciation and trapping of other gaseous radionuclides will worth to be investigated and could benefit from preliminary improvements performed on ^{131}I.

Approach: Mostly based on laboratory experiments

Steps to accomplish:
1) Selection of the most efficient adsorbent regarding its capability to trap efficiently gaseous iodine in humid conditions. Definition of the size and shape of the trap taking into account both the required flow and the size of the detector. Compared with aerosol samplers, some of them having flow rate of several hundred m^3/h, most commercially available gaseous sampler have flow rate between 3 and 10 m^3/h). Characterization of the optimum detection efficiency by Monte Carlo simulation. Prototype building: sampling tests, measurement tests and optimization
Semi-industrial/industrial building.
2) Iodine sorption / desorption kinetics on and from aerosol particle. Possible desorption after deposition.

Outlook:
1) Iodine chemical speciation (I_2, ICH_3, Ox, particulate) with high flow rate (and AMS measurements for ^{129I}),
2) Other gaseous compounds (Ar, Kr, Xe, Rn) pre-concentration steps.

Expected outcomes:
1) Technical: Lower detection limits of gaseous iodine down to 1-10 µBq/m3. Improve chemical speciation for a better dose inhalation assessment. Promote harmonization of sampling equipment. Develop multi-gas sampler
2) processes: knowledge on the gas/particle ratio based on routine ^{129}I releases and transposition to ^{131}I
3) Monitoring strategy: promote routine gaseous monitoring in Europe at a minimum number of sites. In a more effective way, gaseous sampling could be achieved but measurement could occur only if traces are detectable on the particulate form (i.e., on aerosol filters).

Task 3: resuspension and re-emission mechanisms

This task aims to have a better understanding and estimate of the long-term behavior and fate of radionuclides in the atmosphere long after their initial deposition on terrestrial ecosystem. The Japanese society has expressed her strong will for land retrieval and land occupancy. This wish could be disrupted or delayed due to the observation of peaks of airborne activity levels from time to time in Japan. Thresholds for land retrieval based on airborne concentrations may be exceeded on a more or less temporarily period depending on the resuspension or re-emission process involved. Secondary emissions encompassing wind resuspension, biomass burning or biogenic aerosol production (wax exfoliation, pollens, …) are clearly involved in those peaks and in the long lasting persistence of airborne radionuclides in the ground-level air.
The main mechanisms involved are:

- resuspension by wind erosion and human activities (e.g. remediation actions); biomass burnings encompassing combustion of agricultural waste and burning of branches for land clearing, and use of contaminated wood for heating purpose;
- biogenic aerosols (virus, pollens, spores, wax exfoliation)

This task will also cover volcanic eruptions (for thorium, uranium and polonium releases) since there exist only some scarce determinations of their average airborne levels in normal conditions. The 2010 and 2014 volcanic eruptions in Iceland caused important airplane traffic disturbances. ^{210}Po represents a specific volcano tracer and could at least be used to attest the presence of plume residues for insurance activities related to air traffic, and would worth for dose assessment computation for people embedded in plume.

Again, the knowledge of the size distribution will be helpful to characterize the resuspension of radionuclide-labeled aerosol.

Approach:

Mostly based on field experiments and when possible on laboratory experiments (wind tunnel or fire room) to fix the analytical values for microphysical parameters in controlled conditions.

Steps to accomplish:

- Lower the large uncertainties of resuspension coefficient by sorting main parameters (wind speed, vegetation cover, soil type, soil moisture or dryness…),
- Characterization of secondary biogenic emissions depending first on season (pollens, mould, yeast, fungi…) whose size ranges between hundreds nanometers and few micrometers),
- Use of cascade impactors in contaminated areas and in clean areas (to compare with the regional background distribution).

Expected outcomes:

Typical range of values for resuspension coefficient and emission factors according to the magnitude of mechanical parameters (wind speed, shear stress, roughness…) and biogenic production.

^{210}Po baseline in the atmosphere in order to characterize future eruption events.

Time series of air-particles compared to radionuclides (natural and artificial) fluctuations.

Task 4: Plutonium persistence at trace level and time series reconstruction; Characterisation of radioactive particles released from different sources

Approach:

Following high and low temperature nuclear events a large fraction of refractory radionuclides such as uranium and plutonium is present as particles, ranging from submicrons to fragments. The particles can contain a series of radionuclides (fission and activation products) as well as stable metals. These particles serve as input to atmospheric transport models. These particles can carry a substantial fraction of radioactivity, and following deposition, these particles can act as point sources of radiological concern. Deposition of particles in the environment may delay ecosystem transfer. Thus, information on particle weathering rates is essential for assessing long term transfer of particle associated radionuclides.

Steps to accomplish:

- Linking particle characteristics to source and releases scenarios: use of advanced techniques for particle characterisation, and determine particle weathering rates using extraction techniques
- Determination of atom/isotope ratios for source identification (ICP-MS, AMS)

- Possibility of using software for summing spectra of the same sample collected in different periods of time to detect peak (no detectable on individual samples) and to calculate average values.
- Comparison of Soil/Air Plutonium-239 and Plutonium-240 concentrations.

Expected outcomes:
Retrospective time series reconstruction of airborne Pu isotopes,
Sources identification based on atom/isotopic ratio analysis,

Work plan

Partner	Concerned tasks	Means, fundings	Resources
IRSN (France)	Coordination Task 1 Task 2 Task 3 Task 4	 T1: IRSN PhD T2: IRSN, NEEDS-Enviro. T3: IRSN, T4 : IRSN,	T1: 12 + 36 pers.months (PhD) T2: 72 pers.months T3: 12 pers.months T4: 6 pers.months
HMGU (Germany)	Coordination Task 1 Task 2 Task 3 Task 4	 T1: TransAqua, VAO II, HARMONE T2: HMGU T3: TransAqua T4: TransAqua	 T1: 72 pers.months T2: 6 pers.months T3: 12 pers.months T4: 24 pers.months
CERAD (Norway)	Task 3 Task 4	T3: CERAD T4: RATE, CERAD	T3: 6 pers months T¤: 48 pars. months
CIEMAT (Spain)	Task 3 Task 4	T3: UE/National? T4: UE/National?	T3: 24 pers.months T4: 24 pers.months
NCSRD Demokritos (Greece)	Task 1 Task 3	Task 1 : national Task 3 : national	T 1: 36 pers.months T 3: 12 pers.months
SCK-CEN	Task 1	Task 1 : national	T 1: 36 pers.months

Cited projects:
NEEDS- Environnement: French program supported by (CNRS + ANDRA +EDF + IRSN)
TransAqua: German joint project supported by Federal Ministry of Science and Education
VAO II: German program supported by Bavarian State Ministry of Environment
HARMONE: European project funded via OPERRA

Major elements of the communication plan (workshops, publications, guidance documents…)

Partner	
IRSN (France)	COMET meetings, workshops, conferences, publication in international journals
HMGU (Germany)	National workshops, intern. conferences, publication in international journals,
CERAD (Norway)	workshops, conferences, publication in international journals,
CIEMAT (Spain)	workshops, conferences, publication in international journals,

NCSRD Demokritos (Greece)	workshops, conferences, publication in international journals,
SCK-CEN	workshops, conferences, publication in international journals,

Links with other activities identified at the national and the international levels

Partner	
IRSN (France)	Ro5 (Ring of Five network) In Japan: Fukushima University, Meteorological Research Institute, National Institute of Advanced Industrial Science and Technology, Japan Atomic Energy Authority, Ibaraki University
HMGU (Germany)	IAEA-CRP "Environmental Behaviour and Potential Biological Impact of Radioactive Particles"; Ro5 In Japan: Japan Atomic Energy Authority, Fukushima University
CERAD (Norway)	IAEA-CRP "Environmental Behaviour and Potential Biological Impact of Radioactive Particles"
CIEMAT (Spain)	Ro5, ALMERA (IAEA), National Net of environmental radioactivity control, Environmental Radiological Surveillance in Nuclear Installation, National labs Intercomparison Evaluation, DOE-USA
NCSRD Demokritos (Greece)	Ro5
SCK-CEN	Crisis centre of the Federal Public Service (FPS) Internal Affairs, Belgium

Expected problems, gaps/lack of knowledge, etc. that might prevent the accomplishment of the research

As a general comment, airborne activity concentrations are at trace levels (order of µBq/m^3 or less, except for naturally occurring radionuclides). All studies presented here require high-sensitivity detection equipment to overlap detection limits. This is especially the case for Pu isotopes which are sample-consuming and require large number of filter samples.