EUROPEAN RADIOECOLOGY ALLIANCE

ALLIANCE SRA-Statement 2016

The ALLIANCE, the radioecology Strategic Research Agenda and the onset of the Roadmap

The European Radioecology Alliance (ALLIANCE) was founded in 2009 to coordinate and promote European research on radioecology. The ALLIANCE acts as a research platform, defining priorities for research programmes and integrating human and infrastructure resources to advance research in the field of radioecology. It promotes maintenance, updating and mutual use of suitable infrastructures, education and training and communication with stakeholders.

The present statement based on the Strategic Research Agenda[1] (SRA) was produced to serve as an input to those responsible for defining EU research call topics. It provides and justifies research priorities for radioecology at the short- and medium-term consistently with the major outcomes from recent and ongoing projects and with the ALLIANCE SRA, which constitutes the reference document shared by stakeholders and researchers. The strategy underlying the ongoing roadmap development associated to this SRA is driven by the need for improvement of mechanistic understanding across radioecology such that robust fit-for-purpose human and environmental impact/risk assessment can be provided in support of protection of man and the environment, in interaction with society (connecting science, communication, economy) and for the three exposure situations defined by the International Commission on Radiological Protection (*i.e.*, planned, existing and emergency). Several topical working groups[1] each dealing with specific scientific areas and/or complex environmental issues have defined a 5-y topical roadmap: 1) Atmospheric radionuclides in transfer processes, 2) Marine radioecology, 3) Human food chain , 4) Naturally Occurring Radioactive Materials (NORM), 5) Transgenerational effects and species radiosensitivity. Topics 1-3 are mainly linked with NERIS and topic 5 with MELODI. Topics 2-5 are also developed as initial research activities within COMET[2]. The COMET call (2013) supported research in marine radioecology and hot particle environmental behavior. Topics 1 and 3 are also partly covered in the HARMONE task recently granted under the OPERRA 2nd call[3]. Some of the research areas hence provide a powerful catalyst to further increase collaboration between the four European platforms of radiation protection, ALLIANCE, NERIS, MELODI and EURADOS. Since the 2015-SRA statement, there has not been additional trigger to promote major changes in the ALLIANCE priorities. Only two modifications were decided by the ALLIANCE:

(i) to complete the set of ecosystems of interest by adding marine ecosystems to freshwater and terrestrial ones; the objective is mainly to stimulate an integrated and multi-media approach for environmental risk assessment and management, by allowing consideration of processes governing radionuclide fate at interfaces between all ecosystem types and the atmosphere;

(ii) to give the first priority to the topic dedicated to "biomarkers of exposure and effects to living organisms as operational outcome of a mechanistic understanding of radiosensitivity" for two reasons: (1) this topic is not explicitly expressed in any of the two topical areas defining the first CONCERT call in progress at the moment of writing the statement; as a consequence there is no room for proposals linked with effects on non-human species even for mechanistic studies; (2) this is an area of high added value for both human and non-human radiological protection. By regulation, the environment protection needs to be considered and research is needed to unravel the mechanisms behind chronic low-dose, multigenerational effects to enable the derivation of robust environmental protection standards. Human radiation protection may benefit from knowledge acquired on long-term, low dose multigenerational effects.

[1]https://wiki.ceh.ac.uk/x/YoFsD
[2]COMET: COordination and iMplementation of a pan-Europe instrumenT for radioecology. www.comet-radioecology.org
[3] http://www.melodi-online.eu/operra.html

ALLIANCE priorities and ranking

On the basis of (i) our 2015-SRA statement, (ii) discussions/decisions within the ALLIANCE SRA WG and the topical roadmap leaders and their associated WGs, (iii) the timing to release our 2016-statement with no lessons learnt from the first CONCERT call, currently in progress, our priorities are ranked as follows:

- 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, with a focus on the added value for both human and non-human radiological protection **(ranked as priority 1);**
- Environmental availability and impact of radionuclides in terrestrial, freshwater and marine ecosystems (including human food chain) and their interactions with atmosphere, incorporating physical, chemical and/or biological processes. Validated process-based model parameterisation, characterisation of variability and uncertainty, and guidance for fit-for-purpose models **(ranked as priority 2) ;**
- Development of models/tools, and datasets for their calibration and validation and guidance to select and evaluate the effectiveness of different remediation strategies in long-lasting exposure situations (*e.g.* nuclear accidents and/or NORM/TeNORM) **(ranked as priority 3);**
- Multiple stressors and modulation of radiation effects in living organisms **(ranked as priority 4)**.

The ALLIANCE encourages, where relevant openness to other disciplines to integrate their skills and knowledge into radioecology, and capitalisation of best practices, tools and data in the various fields of research needed. Additionally, research combining “lab-field-modelling” approach and fit-for-purpose applications will be appreciated.

ANNEX: Description of ALLIANCE 2016 priorities

Priority title	**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, with a focus on the added value for both human and non-human radiological protection (ranked as priority 1)**
Priority description	The issue of biological effects of low doses of ionising radiation is still of major concern for both human and environmental radiation protection, as highlighted after the Fukushima accident, especially with the aim of quantifying (and reducing if needed) the magnitude of risk to individuals (human and endangered species) and populations (human and biota) health at low doses/dose rates. We need urgently to complement the system of radiation protection to be able to face the wide biodiversity and biological responses to radiation (from molecules to ecosystems) in a credible and robust way. A key for success is to explore intra- and inter-species causes of radiosensitivity variation. This requires reliable quantification of radiosensitivity *in vitro* and ideally also *in vivo*. This will help to screen out candidates for biomarkers to be used as early warning tools after *ad hoc* validation. Research is required to contribute to the identification of the primary mechanisms of radiation induced effects at the molecular level and their propagation up to the individual level, including consequences for physiological functions (*e.g.* reproduction). This will be evidenced by evaluating suitable biomarkers of exposure and biomarkers of effects. A comparative and "lab-field-modelling"-combined approach for a number of exposure conditions and/or a number of species will enhance the understanding of the toxicity profiles as a response to exposure conditions. Dose-response relationships will be established making the best use of "omics" analytical methods, possibly combined with the use of a system biology approach, to provide evidence of linkage between metabolic pathways and associated biomarkers of effects. Research could expand to the use of genetic and epigenetic changes as biomarkers by implementing innovative approaches to test changes in the genome (*e.g.* mutation rates and types) and the epigenome (*e.g.* epigenetic tags) through generations.
European relevance	This topic, synergistic with MELODI, was highly scored in the OPERRA e-survey. It presents a high potential for multidisciplinarity beyond the radiological protection community since it highlights similarities that radioecology has with ecotoxicology, stress ecology and human radiation biology. The topic is indirectly relevant to NERIS in that biomarkers potentially also useful in health surveillance, are looked for. The research is also relevant to EURADOS as accurate dosimetry is a prerequisite for any robust dose-response relationships. Impact on risk communication is expected by providing answers to burning questions emerging from public perception of the consequences of the Fukushima and the Chernobyl accidents. Outcomes will support emerging policy in the field of radioprotection of the environment, explicitly mentioned in the EURATOM Basic Safety Standards.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	This topic will complement human and environmental radiation protection frameworks in a consistent way and will contribute to an improved and efficient integration of both protection frameworks. -MELODI (Aug 2015): p.12-17: chapter 4.2, 4.3. -ALLIANCE (Sept 2013): p.23-30: challenge 2 – research lines 3.2.2.1, 3.2.2.2; 3.2.2.4; p.33: challenge 3-research line 3.3.2.2. -NERIS (Apr 2014): p.18: key topic 5.1; p.20: key topic 5.8; p.23: cross cutting issues. -EURADOS (May 2014): p.7-13: vision 1 topics 1, 2, 3; p.22-25: vision 3 topic 1
Impact: decreased uncertainty	This research should provide the basis for the development of biologically-based extrapolation models which are the key to tackle the wide species diversity and would be useful for risk assessors by helping reducing uncertainty in predictions of effects (and ultimately risk).
Impact: increased radiation protection	Identification of such biomarkers will be relevant to humans or non-human species radiation protection. Acquired knowledge will highlight and feed the various extrapolations needed when assessing radiological risk to humans or non-human species, and will provide robustness in effects predictions and decision making.
Impact: increased quality and reliability	By encouraging openness to other disciplines and innovative hypothesis-driven approach to understand underlying mechanisms, this research topic will contribute to increasing acceptability of the radiation protection system and aid in risk prediction, management and communication.
Feasibility	A wide range of methods and approaches exists to make this research highly feasible, along with effect database (*e.g.* FREDERICA).

Priority title	**Environmental availability and impact of radionuclides in terrestrial, freshwater and marine ecosystems (including human food chain) and their interactions with atmosphere, incorporating physical, chemical and/or biological processes. Validated process-based model parameterisation, characterisation of variability and uncertainty, and guidance for fit-for-purpose models (ranked as priority 2).**
Priority description	A key goal of radioecology is to understand and predict the transfers of radionuclides and consequent exposure of humans and wildlife. More specifically, this is needed for a wide range of sources and release scenarios, exposure situations and assessment contexts in continental environments, including interactions with atmosphere. Although considerable advances have been made since the Chernobyl accident in predictive modelling, the Fukushima accident in Japan has highlighted the need of improved transfer and exposure models. The new models should represent the behaviour of the radionuclides in a more realistic way, ideally considering the different levels of organisation present in the environment. The key physical, chemical and biological processes that govern radionuclide transfers, and how transfers and exposure of humans and wildlife vary spatially, temporally and with the source term, should also be taken into account. Research should contribute to an improved process-based understanding of radionuclide transport and transfers in various radioactively contaminated areas and eventually into the human food chain. Major physical and biogeochemical processes should be identified, conceptualised and mathematically translated into models (from empirical to mechanistic, depending on the requirement) taking into account spatial heterogeneity and temporal variability of the environment under study. One of the expected outcomes is to provide guidance for selecting the level of refinement for models according to the targeted uncertainty. Another is to obtain calibrated and validated models which are fit for purpose.
European relevance	This topic is highly relevant for European radioecology in view of substantial advances in improving process-based understanding of radioecology in Europe, which needs to be supported by adequate funding, allowing European scientists to be leaders in the field. This topic has synergies with MELODI, NERIS and EURADOS, since dose assessment is a key step in the radiological impact/risk characterisation. This synergistic topic was highly scored by the OPERRA e-Survey. The radioecology research lines related with this topic (Challenge 1) also received a high score in the OPERRA e-Survey.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	This topic is multidisciplinary because it connects radioecology, radiation protection, dosimetry, ecotoxicology, physics and biogeochemistry. The topic has links with European research platforms: -ALLIANCE (Sep 2013): p.14-22; Challenge 1; research lines: 3.1.2.1; 3.1.2.2.; 3.1.2.3; and 3.1.2.4; p.32, Challenge 3, research line 3.3.2.1. - NERIS (April 2014): p. 12: key topic 1.6; p. 13: key topic 2.1; p. 16: key topic 3.4; p. 18: key topic 5.1; p.23: cross cutting issues. -EURADOS (May 2014): p.6: vision 3 and 5.
Impact: decreased uncertainty	A deeper scientific understanding of the environmental processes involved in the transport and transfer of radionuclides will reduce uncertainties and hence robustly support decision making in various exposure situations. The knowledge gained will allow providing guidance for selecting the level of refinement for models according to the targeted uncertainty.
Impact: increased radiation protection	The topic will contribute to improve the radiation protection system, since it will allow to accurately predict exposure to humans and wildlife in planned, existing and emergency exposure situations, within continental and marine ecosystems that may interact between each other and with atmosphere.
Impact: increased quality and reliability	Uncertainties and lack of predictive power in risk assessments are major contributors to the public's reduced credibility of radiological sciences. Therefore, the acquisition of new scientific knowledge to reduce the uncertainties of the dose assessments, allowing more robust predictions and improved human and wildlife impact/risk assessments, will improve credibility with stakeholders.
Feasibility	There is a strong European radioecology research base with access to modelling, international databases, long-term collaborations with international organisations and first-class facilities.

Priority title	**Development of models/tools and datasets for their calibration and validation, and guidance to select and evaluate the effectiveness of different remediation strategies in long-lasting exposure situations (*e.g.* nuclear accidents and/or NORM/TeNORM)** (**ranked as priority 3**).
Priority description	Management approaches in emergency and existing exposure situations can range widely in complexity. Although a significant knowledge exists for a wide range of exposure situations, it tends to be fragmentary rather than forming an integrated strategy capable of dealing with complex, dynamically changing conditions. The need for integrated and graded management approaches and the appropriate tools to implement them over the entire spectrum of possible exposure scenarios, and thus ensuring that socio-economic facets are taken into account in the rehabilitation of the impacted areas, are primary drivers for radioecological research in the coming decades. The events at Fukushima after the NPP accident exemplify these problems and the existing deficiencies. There is a need for sound, fundamental and progressive science to yield maximum benefits from these efforts. Research is needed to guide the development/selection of models and assessment tools for medium to long-term predictions. There is a parallel need to generate and make available field data for their validation. Appropriate models (from empirical to process-based) should be developed to help compare radiological effects from various remediation measures, including those reducing radionuclide transfers into the food chain and/or those improving ecosystem services. For relevant radionuclides, models need to be applied to design remediation strategies to the major components of the ecosystems. Regarding more specifically post-accident exposure situations, the research to be done ought to complement the OPERRA-2014 HARMONE project activities, mainly dealing with the early phase of an emergency situation. Regarding NORM/TeNORM sites research is needed to give answers to the specific requirements of the EURATOM Basic Safety Standards (BSS).
European relevance	This topic has synergies with NERIS and EURADOS, in the establishment of priorities for pre-accident recovery preparedness, which was highly scored by OPERRA e-Survey. The topic defined by ALLIANCE will complement the expected outcomes from OPERA-2014 HARMONE, by dealing with medium- to long-term transfer processes and by tackling remediation issues. The topic is relevant to implement the requirements from the EURATOM BSS in relation to NORM/TeNORM. The priority is designed up-front to address specific BSS requirements for long-lasting exposure situations / remediation strategies.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	Multidisciplinarity is assured through topical links between radioecology, radiation protection/dosimetry, ecotoxicology, physics and biogeochemistry. -ALLIANCE (Sept 2013): p. 30-37- challenge 3- research lines 3.3.2.1 to 3.3.2.6; p.14-22: challenge 1- research lines 3.1.2.1 to 3.1.2.4. -NERIS (Apr 2014): p. 12: key topic 1.6; p. 16: key topic 3.4; p. 19: key topic 5.7; p.23: cross cutting issues -EURADOS (May 2014): p.6: vision 3 and 5.
Impact: decreased uncertainty	Scarcity of data is one of the major sources of uncertainty. The databases developed will contribute to the reduction of uncertainties in the impact/risk characterization in long-term radiological assessments, making remediation strategies more credible and robust, and offering the possibilities of comparing a range of strategies. The use of calibrated and validated models will also contribute to reduce uncertainties.
Impact: increased radiation protection	The predictions obtained in the assessment models are often key constituents in decisions made about emergency response, waste management, environmental remediation, and mitigation. The availability of more accurate validated models will increase the confidence in the radiological impact/risk assessment process, and therefore will contribute to the improvement of the radiation protection system through robust evaluation of the best remediation strategies to minimise exposures to the public and the environment.
Impact: increased quality and reliability	The use of validated models will improve the predictive accuracy and precision of the radiological impact assessments, with a greater confidence in the results. Moreover, justification of nuclear industry activities is increased if robust remediation approaches exist and are well evaluated before things go wrong.
Feasibility	The expertise and technological resources needed exist and are well consolidated at the European level to make this research highly feasible.

Priority title	**Multiple stressors and modulation of radiation effects in living organisms (ranked as priority 4)**
Priority description	Exposure to multiple stressors may directly or indirectly modulate radiation effects in living organisms. Even though studying a contaminant in isolation is necessary to understand the underlying mechanisms resulting in the observed effects, this does not allow to predict potential interactions among the many stressors to which organisms are actually exposed and the resulting effects. Interactions can reduce overall damage or augment single stressor effects. Hence, the presence of co-stressors may alter the level at which organisms are likely to show radiation effects. From a risk point of view, knowing how co-contaminants/stressors might influence the radiosensitivity of organisms is therefore a pressing need. Research is required to contribute to the mechanistic understanding of how radiation effects in living organisms are modulated in the context of multiple stressors. Emphasis is on environmentally relevant combinations of stressors that interact such that synergistic effects are likely to occur with exposure to radiation or radionuclides. The occurrence of synergisms will have to be investigated at realistic radiation levels and realistic concentrations/conditions of other stressors. Given the multitude of potential stressors and combinations that exists in real exposure conditions, the approach to prioritise hypotheses, select stressor combinations and conditions is quintessential. Projects should be directed to the mechanistic understanding of the site where interactions occur: at the level of exposure, where interactions can take place in various processes (*e.g.* uptake, internal distribution of the radionuclides), or at the level of effect (where interactions could be observed at the primary site(s) of disturbance or in regulation and signal transduction of the response of the organism following exposure). Dynamic and biology-based methods and approaches (*e.g.* DEBtox, gene expression pathways) could contribute to mechanistic understanding. Multiple stressor research will benefit from field based studies and the evaluation of the results in a risk assessment context. The question of the robustness of screening values in a multiple stressor context should be considered.
European relevance	This multidisciplinary complex topic can build on the achievements of the STAR Network of Excellence and was selected as a high importance synergistic topic by ALLIANCE, MELODI and EURADOS. The research on this topic will help reduce uncertainties by taking into account environmentally relevant exposure conditions. The research is relevant to EURADOS as accurate dosimetry is a prerequisite for any robust dose-response relationships. Impact in communication to the public is expected by improving the capability of demonstrating the impact of ionising radiation in comparison to other environmental stressors.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	This topic will support chemical and radiological environmental protection frameworks in a consistent way and will improve consistency for any environmental impact assessment. This research is highly multidisciplinary in nature and will benefit from interacting with ecotoxicology and biochemistry. -MELODI (Aug 2015): p.17: synergistic topic 1. -ALLIANCE (Sept 2013): p.27: challenge 2 – research line 3.2.2.3; p.34: challenge 3-research line 3.3.2.3. -NERIS (Apr 2014): p. 16: key topic 3.6; p.23: cross cutting issues.-EURADOS (May 2014):): p.7-13: vision 1 topics 1, 2, 3; p.22-25: vision 3 topic 1
Impact: decreased uncertainty	This research will complete the scientific foundation for fully integrating environmental and human protection frameworks under one generalised system (*i.e.* consistent between radiation and chemicals on one hand and human and environment on the other hand), which would be of much interest to regulators, industry and the public.
Impact: increased radiation protection	This research will demonstrate if radiation protection standards are robust and protective enough. Will provide robustness to any risk assessment, associated decisions and communication.
Impact: increased quality and reliability	Gaining knowledge on low dose effects under realistic exposure conditions and explaining clearly important and relevant results obtained to the public are needed to give people the power of informed choice and of making decisions knowing the level of risks associated to their living conditions for them and the future generations. Being able to clearly demonstrate the role of ionising radiation in comparison to any other environmental stressor is a must for being successful.
Feasibility	This research needs to implement an innovative approach and as such, is risky.